Request by GX Technology to Allow the Incidental Take of Marine Mammals During a Marine Seismic Survey of the Chukchi Sea, June – November 2006

submitted by

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3 April 2006

LGL Report P892-1a

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Request by GX Technology for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals During a Marine Seismic Survey of the Chukchi Sea, June – November 2006

SUMMARY

GX Technology (GXT) plans to conduct a 2D marine seismic survey in the Chukchi Sea during the period 15 June to 30 November 2006 (approximately). GXT requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey in the Chukchi Sea within U.S. Minerals Management Service (MMS) Lease Sale areas. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

The seismic survey is designed to collect 2D data of the deep sub-surface in the Chukchi Sea to better evaluate the evolution of the petroleum system at the basin-level. The data will help identify source rocks, migration pathways, and play types.

Several species of cetaceans and pinnipeds inhabit the Chukchi Sea. Few species that may be found in the study area are listed as "Endangered" under the U.S. Endangered Species Act (ESA). The bowhead whale is the one endangered species that is likely to occur within the survey area. The location and timing of survey activities have been scheduled to avoid the spring and fall bowhead whale migration near subsistence use areas. GXT will not survey nearshore within the Chukchi polynya zone where marine mammals are known to migrate in the spring. GXT is proposing a marine mammal monitoring and mitigation program to minimize the impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects.

The items required to be addressed pursuant to 50 C.F.R. § 216.104, "Submission of Requests" are set forth below. This includes descriptions of the specific operations to be conducted, the marine mammals occurring in the study area, proposed measures to mitigate against any potential injurious effects on marine mammals, and a plan to monitor behavioral effects of the operations on marine mammals. A related Application has been submitted to the U.S. Fish & Wildlife Service with regard to potential effects on species managed by USFWS – the walrus and polar bear

I. OPERATIONS TO BE CONDUCTED

A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

Overview of the Activity

GX Technology (GXT) plans to conduct a 2D marine seismic survey in the Chukchi Sea (Fig. 1) for ~100 days during the period 15 June to 30 November 2006. Depending on ice conditions, the seismic vessel, M/V *Discoverer*, will mobilize from Dutch Harbor and travel to the Chukchi Sea survey area ~mid-June to commence the survey. GXT intends, as soon as ice conditions allow (~ late July), to leave the Chukchi Sea and travel across the Alaskan Beaufort to the Canadian Beaufort Sea. GXT plans to conduct seismic operations in the Canadian Beaufort Sea until the survey is completed or for as long as ice conditions and subsistence hunting considerations allow. The *Discoverer* will then return to the Chukchi Sea to resume surveying until the transect lines in the area are completed or weather and sea ice force an end to the survey season. The survey season in the Chukchi Sea is not expected to continue past 30 November 2006. Dates are close approximates given the uncertainties in ice conditions and other factors.

The purpose of the proposed study is to collect seismic reflection data that reveal the sub-bottom profile for assessments of petroleum reserves in the area. Ultra-deep 2D lines such as those to be collected, are used to better evaluate the evolution of the petroleum system at the basin level, including identifying source rocks, migration pathways, and play types. All planned geophysical data acquisition activities will be conducted by GXT.

The geophysical survey will be performed from the M/V *Discoverer*, a vessel owned by Shangshai Offshore Petroleum Bureau. The seismic survey is expected to begin in the Chukchi Sea >25 km off the coast near Cape Lisburne, Alaska, ~15 June 2006, ice conditions permitting. The *Discoverer* will tow an airgun array directly astern and a single hydrophone streamer up to 9 km long. The array will consist of 36 sleeve airguns (8 × 40 in^3, 4 × 70 in^3, 4 × 80 in^3, 12 × 100 in^3, 8 × 150 in^3) that produce a total discharge of 3320 in^3. The vessel will travel along pre-determined lines at ~4–5 knots while the airgun array discharges every ~20 seconds (shot interval ~46 m). The towed hydrophone streamer will receive the reflected signals and transfer the data to an on-board processing system. The proposed survey lines cover a large portion of the Chukchi Sea (Fig. 1), and tie together known wells, core locations, fault lines and other geophysical points of interest. Specifications of the M/V *Discoverer* and the 36-airgun array that will be used are included as Appendices A and B, respectively.

The entire program, if it can be completed, will consist of a total of ~5302 km of surveys, not including transits when the airguns are not operating (Fig. 1). Water depths within the study area are 30–3800 m. Approximately 14% of the survey (~742 km) will occur in water depths >500 m, 5% of the survey (~265 km) will be conducted in water 200–500 m deep, and most (81%) of the survey (~4295 km) will occur in water <200 m. The survey consists of a large grid of 14 lines oriented to connect previous well locations and core sample locations as well as geological structures in the sub-surface. The extent of the lines allows flexibility to mitigate any interaction with seasonal subsistence hunting as well as species migration patterns. GXT has restricted its survey lines along the shore to the area of the MMS lease sales (>25 km offshore) to exclude the nearshore Chukchi polynya, through which marine mammals migrate in the spring. Lines will be chosen based on marine mammal migration and subsistence hunting, as well as ice movement and geophysical importance. If heavy ice conditions are encountered in the northern portions of the survey area (Fig. 1), some trackline planned for that region may be shifted to ice-free waters within the central or southern portions of the survey area. There will be additional seismic operations associated with airgun testing, start up, and repeat coverage of any areas where initial data quality is sub-standard. In addition to the airgun array, a pinger system will be used to position the 36-airgun array and streamer relative to the vessel.

This is a privately-funded research effort. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise. The *Discoverer* will serve as the platform from which vessel-based marine mammal observers will watch for marine mammals before and during airgun operations. MONITORING AND REPORTING PLAN. A "chase boat" will also be used to protect the streamer from damage and otherwise lend support to the *Discoverer*. It will not be introducing sounds into the water beyond those associated with normal vessel operations. Helicopter operations are not planned as a part of the seismic survey and would occur only in the case of an emergency.

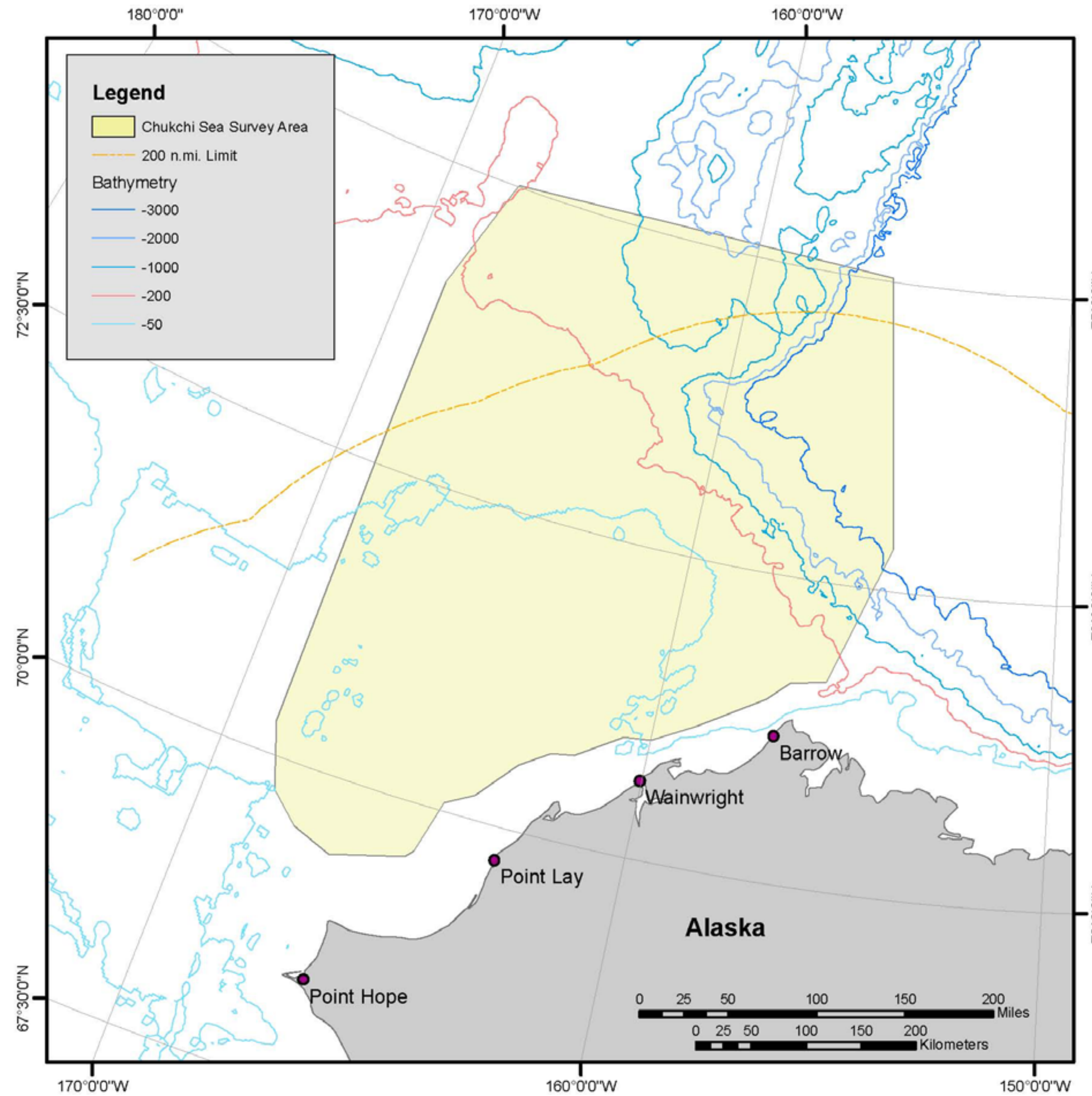


FIGURE 1. Proposed location of GXT's ~June–November 2006 Chukchi Sea seismic survey area.

Safety Radii

The rms (root mean square) received sound pressure levels that are used as impact criteria for marine mammals under U.S. procedures are not directly comparable to the peak or peak-to-peak values normally used by geophysicists to characterize source levels of airguns (Appendix C). The measurement units used to describe airgun sources, peak or peak-to-peak dB, are always higher than the rms dB referred to in much of the biological literature and in the NMFS criteria. A measured broadband received level of 160 dB re 1 μPa (rms) in the far field would typically correspond to a peak measurement of about 170 to 172 dB, and to a peak-to-peak measurement of about 176 to 178 decibels, *as measured for the same pulse received at the same location* (Greene 1997; McCauley et al. 1998, 2000a). The precise difference between rms and peak or peak-to-peak values for a given pulse depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source. Additional discussion of the characteristics of airgun pulses is included in Appendix C.

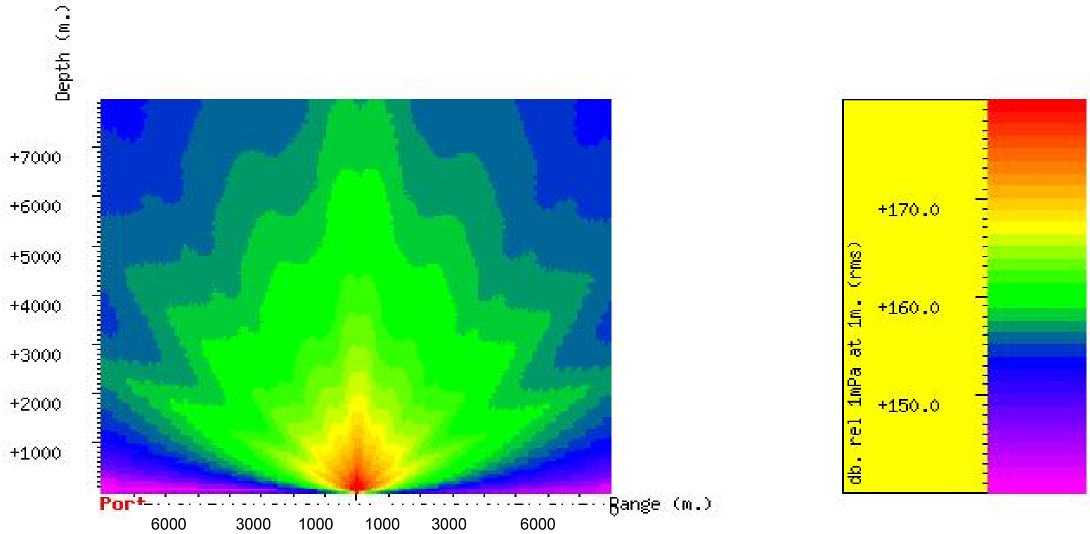
Received sound fields have been modeled by GXT using the Gundalf software suite (Gundalf 2002) for the 36-airgun array that will be used during this survey (Appendix B). GXT used an advanced version of the Gundalf modeling program to estimate the rms received sound levels (in dB re 1 μPa) at different distances from the seismic source on a broadband basis (0–256 Hz; Fig. 2 and 3). These estimates are believed by GXT to be conservative (i.e., likely to overestimate the distance at which received levels will be ≥160 dB) and most applicable to the 36 airgun array discharging 3320 in^3 in water depths between 200 and 500 m, or "intermediate depths". The estimated radii are expected by GXT to be less in "deep" (>500 m) and "shallow" (<200 m) water. Empirical data do not exist for this airgun array's sound propagation, so those data will be collected at the beginning of seismic operations. During this initial period, a 1.5× precautionary factor will be applied to the 190 dB and 180 dB radii listed in Table 1, for use as shutdown radii for marine mammals in the water. Once empirical measurements of the sound produced by GXT's airgun array have been collected, the safety radii presented in Table 1 may be adjusted to reflect those results.

For purposes of estimating exposures in this document, the intermediate depth radii (expected by GXT to be the largest of the radii for any of the three water depth categories) will be used along tracklines occurring in all three depth categories. This precautionary procedure will likely overestimate the area ensonified and therefore the numbers of marine mammals exposed to various applicable received sound levels.

The airguns will be powered down immediately (or shut down if necessary) when marine mammals are detected **in the water** at locations within or about to enter the appropriate ≥180 dB or ≥190 dB radii. A single 40 in^3 sleeve airgun will be used as the power down source. The 160–190 dB re 1 μPa (rms) radii for this source will be measured during acoustic verification measurements at the beginning of seismic shooting. The ≥180 and ≥190 dB safety criteria are consistent with guidelines listed for cetaceans and pinnipeds, respectively, by NMFS (2000) and other guidance by NMFS. As described above, a 1.5× precautionary factor will be applied to the modeled ≥180 dB and ≥190 dB radii for use during the initial seismic operations until empirical measurements of received sound levels vs. distance can be made and radii revised accordingly.

GTX is aware that NMFS may release new noise-exposure guidelines soon (NMFS 2005). See http://mmc.gov/sound/plenary2/pdf/gentryetal.pdf for preliminary recommendations concerning the new criteria. GTX will be prepared to revise its procedures for estimating numbers of mammals "taken", safety radii, etc., as may be required by the new guidelines, if issued.

2.



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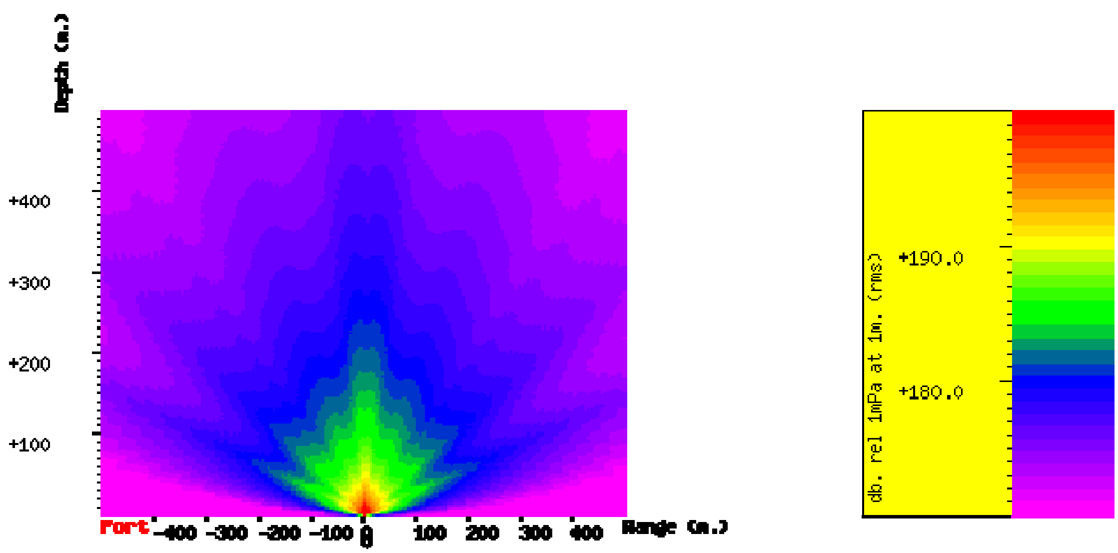

FIGURES 2 AND 3. Modeled rms received sound levels from the 36-airgun array that will be used during the proposed seismic survey in the eastern Chukchi Sea, 15 June – 30 November, 2006. Figure 2, extending to ~7 km depth and radius, shows the predicted 160 dB re 1 μPa (rms) and similar distances. Figure 3, extending to ~500 m, better illustrates the predicted 170, 180 and 190 dB re 1 μPa (rms) distances. The model assumes frequency-independent transmission loss of 15 log (r) and is most applicable to intermediate water depths (200–500 m). Results derived from this model are believed by GXT to overestimate the received levels of sound in shallow (<200 m) and deep (>500 m) waters. Predictions are based on Gundalf model computations provided by GXT (Gundalf 2002).

TABLE 1. Estimated distances to which sound levels ≥190, 180, 170, and 160 dB re 1 μPa (rms) might be received from a 36-airgun array (8 × 40 in^3, 4 × 70 in^3, 4 × 80 in^3, 12 × 100 in^3, 8 × 150 in^3) that will be used during the seismic survey. The ≥190 and ≥180 dB radii will be scaled upward by a factor of 1.5× when defining the shut-down radii to be applied before empirical sound level data are collected for this airgun array. The shut-down and assumed harassment radii used during the survey will be adjusted depending on results of empirical measurements conducted at the start of seismic shooting, and may vary with depth (see text). A single 40 in^3 G. gun will be used during power downs, and empirical measurements of that source will be made at the start of seismic shooting to determine the power down safety radii. Distances are based on Gundalf model computations provided by GXT (Gundalf 2002).

		Estimated Distances for Received Levels (m)			
Seismic Source Volume	Water depth	**190 dB** (shut-down criterion for pinnipeds)	**180 dB** (shut-down criterion for cetaceans)	**170 dB** (alternate behavioral harassment criterion for delphinids & pinnipeds)	**160 dB** (assumed onset of behavioral harassment)
3320 in^3 (36-airgun array)	<200 m	60	250	1250	6000
	200–500 m	60	250	1250	6000
	>500 m	60	250	1250	6000

II. DATES, DURATION, AND REGION OF ACTIVITY

The date(s) and duration of such activity and the specific geographical region where it will occur.

The *Discoverer* will arrive in Dutch Harbor ~1 June where she will be resupplied and the crew will change in preparation for the beginning of seismic surveys in the Chukchi Sea. Depending on ice conditions, the vessel will mobilize to arrive off Cape Lisburne and begin survey data acquisition as soon as possible - expected date is ~15 June 2006. Two alternative schedule scenarios are planned depending on the seasonal ice conditions encountered in 2006.

The primary (and most likely) scenario entails operations beginning in the Chukchi Sea on ~15 June 2006. Collection of seismic data will continue there until ~25 July, or whenever there is sufficient open water near Point Barrow and in the Alaskan Beaufort Sea to allow passage east into the Canadian Beaufort Sea. The *Discoverer* will then proceed out of the Chukchi Sea, traverse the Alaskan Beaufort Sea, and begin surveying within the Canadian Beaufort Sea. Seismic operations will continue in the Canadian Beaufort Sea until all planned seismic lines have been completed, or new ice begins forming in the fall. The vessel will then travel west across the Beaufort Sea and return to the Chukchi Sea to complete any lines not surveyed in July, or until weather and sea ice force an end to the survey season, which is not expected to continue past 30 November 2006.

The second scenario will occur only if sea ice in the Beaufort Sea does not move far enough offshore to allow the *Discoverer* to travel to the Canadian Beaufort. In that case, the vessel will continue operations in the Chukchi Sea until all survey lines there are completed. The *Discoverer* will then exit the area and transit to Dutch Harbor to de-mobilize. Helicopter operations are not planned as a part of the seismic survey and would occur only in the case of an emergency.

The proposed seismic survey activities will take place across a large portion of the eastern and northern Chukchi Sea (Fig. 1). The overall area within which the seismic survey will occur is located approximately between 69º15' and 75º00'N, and between 154º30'W and 169º00'W (Fig. 1). The survey will consist of a total of ~5302 km of surveys, not including transits when the airguns are not operating. The seismic survey will take place in water depths 30–3800 m. Approximately 14% of the survey (~742 km) will occur in water depths >500 m, 5% of the survey (~265 km) will be conducted in water 200–500 m deep, and most (81%) of the survey (~4295 km) will occur in water <200 m. None of the survey will take place in nearshore waters within 25 km of the coast (the Chukchi polynya zone).

III. Species and Numbers of Marine Mammals in Area

The species and numbers of marine mammals likely to be found within the activity area.

A total of 8 cetacean species, 4 species of pinnipeds, and 1 marine carnivore are known to or may occur in or near the proposed study area (Table 2). Two of these species, the bowhead and fin whale, are listed as "Endangered" under the ESA, but the fin whale is unlikely to be encountered along the planned tracklines.

The marine mammals that occur in the proposed survey area belong to three taxonomic groups: odontocetes (toothed cetaceans, such as beluga whale and narwhal), mysticetes (baleen whales), and carnivora (pinnipeds and polar bears). Cetaceans and pinnipeds (except walrus) are the subject of this IHA Application to NMFS. In the U.S., the walrus and polar bear are managed by the U.S. Fish & Wildlife Service. A separate IHA Application for this survey has been submitted to USFWS for incidental "takes" specific to walruses and polar bears.

To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in Section IV, below.

IV. Status, Distribution and Seasonal Distribution of Affected Species or Stocks of Marine Mammals

A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities

Sections III and IV are integrated here to minimize repetition.

The marine mammal species most likely to be encountered during the seismic survey include two cetacean species (beluga and bowhead whale), four pinniped species (ringed seal, bearded seal, spotted seal, and walrus), and the polar bear. Most encounters are likely to occur along the ice edge. No surveying will occur in the nearshore area, within 25 km of shore, where animal densities would be relatively high. Animal densities are generally expected to be lower in the offshore waters where the proposed survey would take place. The marine mammal likely to be encountered most widely (in space

TABLE 2. The habitat, abundance in the Chukchi Sea area, and conservation status of marine mammals inhabiting the proposed study area.

Species	Habitat	Abundance	ESA[1]	IUCN[2]	CITES[3]
Odontocetes Beluga whale (*Delphinapterus leucas*)	Offshore, Coastal, Ice edges	50,000[4] 39,257[5]	Not listed	VU	II
Killer whale (*Orcinus orca*)	Widely distributed	Rare	Not listed	LR-cd	II
Harbor Porpoise (*Phocoena phocoena*)	Coastal, inland waters	Extralimital	Not listed	VU	II
Mysticetes Bowhead whale (*Balaena mysticetus*)	Pack ice & coastal	10,545[6]	Endangered	LR-cd	I
Gray whale (*Eschrichtius robustus*) (eastern Pacific population)	Coastal, lagoons	488[7] 17,500[8]	Not listed	LR-cd	I
Minke whale (*Balaenoptera acutorostrata*)	Shelf, coastal	0	Not listed	LR-cd	I
Fin whale (*Balaenoptera physalus*)	Slope, mostly pelagic	0	Endangered	EN	I
Pinnipeds Walrus (*Odobenus rosmarus*)	Coastal, pack ice, ice	188,316[9]	Not listed	–	II
Bearded seal (*Erignathus barbatus*)	Pack ice	300,000-450,000[10] 4863[11]	Not listed	–	–
Spotted seal (*Phoca largha*)	Pack ice	1000[12]	Not listed	–	–
Ringed seal (*Pusa hispida*)	Landfast & pack ice	Up to 3.6 million [13] 245,048[14] 326,500[15]	Not listed	–	–
Carnivora Polar bear (*Ursus maritimus*)	Coastal, ice	>2500[16] 15,000[17]	Not listed	LR-cd	–

[1] U.S. Endangered Species Act.
[2] IUCN Red List of Threatened Species (2003). Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened; -lc = Least Concern); DD = Data Deficient.
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004).
[4] Total Western Alaska population, including Beaufort Sea animals that occur there during migration and in winter (Small and DeMaster 1995).
[5] Beaufort Sea population (IWC 2000).
[6] Abundance of bowheads surveyed near Barrow, as of 2001 (George et al. 2004); revised to 10,545 by Zeh and Punt (2005).
[7] Southern Chukchi Sea and northern Bering Sea (Clark and Moore 2002).
[8] North Pacific gray whale population (Rugh 2003 *in* Keller and Gerber 2004) ; see also Rugh et al. (2005).
[9] Pacific walrus population (USFWS 2000a).
[10] Alaska population (USDI/MMS 1996).
[11] Eastern Chukchi Sea population (NMML, unpublished data).
[12] Alaska Beaufort Sea population (USDI/MMS 1996).
[13] Alaska estimate (Frost et al. 1988 *in* Angliss and Lodge 2004).
[14] Bering/Chukchi Sea population (Bengtson et al. 2005).
[15] Alaskan Beaufort Sea population estimate (Amstrup 1995).
[16] Amstrup et al. (2001).
[17] NWT Wildlife and Fisheries, http://www.nwtwildlife.rwed.gov.nt.ca/Publications/speciesatriskweb/polarbear.htm

and time) throughout the cruise is the ringed seal. Other widely distributed marine mammals are expected to include the beluga whale, bearded seal, and polar bear. Encounters with bowhead and gray whales are expected to be limited to particular regions and seasons, as discussed below.

Four additional cetacean species—the killer whale, harbor porpoise, minke whale, and fin whale—could occur in the project area, but each of these species is rare or extralimital in the area and not likely to be encountered. Killer whales and harbor porpoises could be encountered in the Chukchi Sea, but both species are rare in the region. Minke and fin whales are extralimital in the Chukchi Sea.

(1) Odontocetes

(a) Beluga (*Delphinapterus leucas*)

The beluga whale is an arctic and subarctic species that includes several populations in Alaska and northern European waters. It has a circumpolar distribution in the Northern Hemisphere and occurs between 50º and 80ºN (Reeves et al. 2002). It is distributed in seasonally ice-covered seas and migrates to warmer coastal estuaries, bays, and rivers in summer for molting (Finley 1982).

In Alaska, beluga whales comprise five distinct stocks: Beaufort Sea, eastern Chukchi Sea, eastern Bering Sea, Bristol Bay, and Cook Inlet (O'Corry-Crowe et al. 1997). For the proposed project, only the eastern Chukchi Sea and Beaufort Sea stocks may be encountered. Beluga whales of the Beaufort Sea population are most likely to be observed during their late summer/fall migration between their eastern Beaufort Sea summer feeding grounds and their Bering Sea wintering grounds.

The ***eastern Chukchi Sea*** population is estimated at 3710 animals (Angliss and Lodge 2004). This estimate is based on surveys conducted in 1989–1991. Survey effort was concentrated on the 170 km long Kasegaluk Lagoon where belugas are known to occur during the open-water season. The actual number of beluga whales recorded during the surveys was much lower. Correction factors to account for animals that were underwater and for the proportion of newborns and yearlings that were not observed due to their small size and dark coloration were used to calculate the estimate. The estimate is considered to be a minimum population estimate for the eastern Chukchi stock because the surveys on which it was based did not include offshore areas where belugas are also likely to occur. This population is considered to be stable. It is assumed that beluga whales from the eastern Chukchi stock winter in the Bering Sea (Angliss and Lodge 2004).

Although beluga whales are known to congregate in Kasegaluk Lagoon during summer, evidence from a small number of satellite-tagged animals suggests that some of these whales may subsequently range into the Arctic Ocean north of the Beaufort Sea. Suydam et al. (2005) put satellite tags on 23 beluga whales captured in Kasegaluk Lagoon in late June and early July 1998–2002. Five of these whales moved far into the Arctic Ocean and into the pack ice to 79–80°N. These and other whales moved to areas as far as 1,100 km offshore between Barrow and the Mackenzie River delta spending time in water with 90% ice coverage.

Beluga whales from the eastern Chukchi Sea stock are an important subsistence resource for residents of the village of Point Lay, adjacent to Kasegaluk Lagoon, and other villages in northwest Alaska. Each year, hunters from Point Lay drive belugas into the lagoon to a traditional hunting location. The belugas have been predictably sighted near the lagoon from late June through mid to late July (Suydam et al. 2001).

Pod structure in beluga groups appears to be along matrilineal lines, with males forming separate aggregations. Small groups are often observed traveling or resting together. Belugas often migrate in groups of 100 to 600 animals (Braham and Krogman 1977). The relationships between whales within groups are not known, although hunters have reported that belugas form family groups with whales of different ages traveling together (Huntington 2000).

The ***Beaufort Sea population*** was estimated to contain 39,258 individuals as of 1992 (Angliss and Lodge 2004). This estimate is based on the application of a sightability correction factor of 2× to the 1992 uncorrected census of 19,629 individuals made by Harwood et al. (1996). This estimate was obtained from a partial survey of the known range of the Beaufort Sea population and may be an under-estimate of the true population size. This population is not considered by NMFS to be a strategic stock and is believed to be stable or increasing (DeMaster 1995).

Beluga whales of the Beaufort stock winter in the Bering Sea, summer in the eastern Beaufort Sea, and migrate in offshore waters of western and northern Alaska (Angliss and Lodge 2002). The majority of belugas in the Beaufort stock migrate into the Beaufort Sea in April or May, although some whales may pass Point Barrow as early as late March and as late as July (Braham et al. 1984; Ljungblad et al. 1984; Richardson et al. 1995).

Much of the Beaufort Sea seasonal population enters the Mackenzie River estuary for a short period during July–August to molt their epidermis, but they spend most of the summer in offshore waters of the eastern Beaufort Sea, Amundsen Gulf and more northerly areas (Davis and Evans 1982; Harwood et al. 1996; Richard et al. 2001). Belugas are rarely seen in the central Alaskan Beaufort Sea during the early summer. During late summer and autumn, most belugas migrate westward far offshore near the pack ice (Frost et al. 1988; Hazard 1988; Clarke et al. 1993; Miller et al. 1999). Moore (2000) and Moore et al. (2000b) suggest that beluga whales select deeper slope water independent of ice cover. However, during the westward migration in late summer and autumn, small numbers of belugas are sometimes seen near the north coast of Alaska (e.g., Johnson 1979). Nonetheless, the main fall migration corridor of beluga whales is ~100+ km north of the coast. Satellite-linked telemetry data show that some belugas of this population migrate west considerably farther offshore, as far north as 76º to 78ºN latitude (Richard et al. 1997, 2001).

In summary, beluga whales of the eastern Chukchi population could be encountered in the NE Chukchi Sea . Members of the Beaufort Sea stock are most likely to be encountered within the Chukchi survey area during their late summer/fall migration back to the Bering Sea wintering grounds.

(b) Killer Whale (*Orcinus orca*)

Killer whales are cosmopolitan and globally fairly abundant. The killer whale is very common in temperate waters, but it also frequents the tropics and waters at high latitudes. Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999). The greatest abundance is thought to occur within 800 km of major continents (Mitchell 1975) and the highest densities occur in areas with abundant prey. Both resident and transient stocks have been described. The resident and transient types are believed to differ in several aspects of morphology, ecology, and behavior including dorsal fin shape, saddle patch shape, pod size, home range size, diet, travel routes, dive duration, and social integrity of pods (Angliss and Lodge 2004).

Killer whales are known to inhabit almost all coastal waters of Alaska, extending from southeast Alaska through the Aleutian Islands to the Bering and Chukchi seas (Angliss and Lodge 2004). Killer whales probably do not occur regularly in the Beaufort Sea although sightings have been reported (Leatherwood et al. 1986; Lowry et al. 1987). George et al. (1994) reported that they and local hunters see a few killer whales at Point Barrow each year. Killer whales are more common southwest of Barrow in the southern Chukchi Sea and the Bering Sea. Killer whales from either the North Pacific resident or transient stock could occur in the Chukchi Sea during the summer. The number of killer whales likely to occur in the Chukchi Sea during the proposed activity is unknown. Based on photographic techniques, ~100 animals have been identified further south in the Bering Sea (ADFG 1994).

(c) Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise is a small odontocete that inhabits shallow, coastal waters—temperate, subarctic, and arctic—in the Northern Hemisphere (Read 1999). Harbor porpoises occur mainly in shelf areas where they can dive to depths of at least 220 m and stay submerged for more than 5 min (Harwood and Wilson 2001) feeding on small schooling fish (Read 1999). Harbor porpoises typically occur in small groups of only a few individuals and tend to avoid vessels (Richardson et al. 1995).

The subspecies *P. p. vomerina* ranges from the Chukchi Sea, Pribilof Islands, Unimak Island, and the south-eastern shore of Bristol Bay south to San Luis Obispo, California. Point Barrow, Alaska, is the approximate northeastern extent of their regular range (Suydam and George 1992), though there are extra-limital records east to the mouth of the Mackenzie River in the Northwest Territories, Canada.

Although separate harbor porpoise stocks for Alaska have not been identified, Alaskan harbor porpoises have been divided into three groups for management purposes. These groups include animals from southeast Alaska, Gulf of Alaska, and Bering Sea populations. Chukchi Sea harbor porpoises belong to the Bering Sea group which includes animals from Unimak Pass northward. Based on aerial surveys in 1999, the Bering Sea population was estimated at 47,356 animals, although this estimate is likely conservative as the surveyed area did not include known harbor porpoise range near the Pribilof Islands or waters north of Cape Newenhan (~55°N; Angliss and Lodge 2004). Suydam and George (1992) suggested that harbor porpoises occasionally occur in the Chukchi Sea and reported nine records of harbor porpoise in the Barrow area in 1985–1991.

Harbor porpoises are likely to occur in coastal and perhaps shelf waters of the Chukchi Sea in small numbers. No seismic surveying is planned for areas within 25 km of shore in the Chukchi Sea, reducing the probability of encountering harbor porpoises.

(2) Mysticetes

(a) Bowhead Whale (*Balaena mysticetus*)

Bowhead whales only occur at high latitudes in the northern hemisphere and have a disjunct circumpolar distribution (Reeves 1980). Bowheads are one of only three whale species that spend their entire lives in the Arctic. Bowhead whales are found in the western Arctic (Bering, Chukchi, and Beaufort seas), the Canadian Arctic and West Greenland (Baffin Bay, Davis Strait, and Hudson Bay), the Okhotsk Sea (eastern Russia), and the Northeast Atlantic from Spitzbergen westward to eastern Greenland. Five stocks are recognized for management purposes. The largest is the Western Arctic or Bering–Chukchi–Beaufort (BCB) stock, which includes whales that winter in the Bering Sea and migrate through the Bering Strait, Chukchi Sea and Alaskan Beaufort Sea to the Canadian Beaufort Sea, where they feed during the summer.

The BCB stock of bowhead whales winter in the central and western Bering Sea and many of them summer in the Canadian Beaufort Sea (Moore and Reeves 1993). Spring migration through the Chukchi and the western Beaufort Sea occurs through offshore ice leads, generally from March through mid-June (Braham 1984; Moore and Reeves 1993).

Some bowheads arrive in coastal areas of the eastern Canadian Beaufort Sea and Amundsen Gulf in late May and June, but most may remain among the offshore pack ice of the Beaufort Sea until mid summer. After feeding in the Canadian Beaufort Sea, bowheads migrate westward from late August through mid or late October. Fall migration into Alaskan waters is primarily during September and October. However, in recent years a small number of bowheads have been seen or heard offshore from the Prudhoe Bay region during the last week of August (Treacy 1993; LGL and Greeneridge 1996; Greene 1997; Greene et al. 1999; Blackwell et al. 2004). Consistent with this, Nuiqsut whalers have stated that the earliest arriving bowheads have apparently reached the Cross Island area earlier in recent years than formerly (T. Napageak, pers. comm.).

The Minerals Management Service (MMS) has conducted or funded late-summer/autumn aerial surveys for bowhead whales in the Alaskan Beaufort Sea since 1979 (e.g., Ljungblad et al. 1986, 1987; Moore et al. 1989; Treacy 1988–1998, 2000, 2002a,b; Monnett and Treacy 2005; Treacy et al. 2006). Bowheads tend to migrate west in deeper water (farther offshore) during years with higher-than-average ice coverage than in years with less ice (Moore 2000b; Treacy et al. 2006). In addition, the sighting rate tends to be lower in heavy ice years (Treacy 1997:67). During fall migration, most bowheads migrate west in water ranging from 15 to 200 m deep (Miller et al. 2002 *in* Richardson and Thomson 2002). Some individuals enter shallower water, particularly in light ice years, but very few whales are ever seen shoreward of the barrier islands in the Alaskan Beaufort Sea. Survey coverage far offshore in deep water is usually limited, and offshore movements may have been underestimated. However, the main migration corridor is over the continental shelf.

In autumn, westward-migrating bowhead whales typically reach the Kaktovik and Cross Island areas in early September, and that is when the subsistence hunts for bowheads typically begin in those areas (Kaleak 1996; Long 1996; Galginaitis and Koski 2002; Galginaitis and Funk 2004, 2005; Koski et al. 2005). The hunts at those two locations usually have ended by 30 September.

Westbound bowheads typically reach the Barrow area in mid-September, and are in that area until late October (e.g., Brower 1996). However, over the years, local residents report having seen a small number of bowhead whales feeding off Barrow or in the pack ice off Barrow during the summer. Bowhead whales that are thought to be part of the Western Arctic stock may also occur in small numbers in the Bering and Chukchi seas during the summer (Rugh et al. 2000 *in* Angliss and Lodge 2004). Autumn bowhead whaling near Barrow normally begins in mid-September, but may begin as early as August if whales are observed and ice conditions are favorable (USDI/BLM 2005). Whaling near Barrow can continue into October, depending on the quota and conditions.

The pre-exploitation population of bowhead whales in the Bering, Chukchi, and Beaufort seas is estimated to have been 10,400-23,000 whales. Commercial whaling activities may have reduced this population to perhaps 3000 animals (Woodby and Botkin 1993). Up to the early 1990s, the population size was believed to be increasing at a rate of about 3.2% per year (Zeh et al. 1996; Angliss and Lodge 2002) despite annual subsistence harvests of 14–74 bowheads from 1973 to 1997 (Suydam et al. 1995; § IV). Allowing for an additional census in 2001, the latest estimates are based on an annual population growth rate of 3.4% (95% CI 1.7–5%) from 1978 to 2001 and a population size (in 2001) of ~10,470 animals (George et al. 2004, recently revised to 10,545 by Zeh and Punt [2005]). Assuming a continuing annual population growth of 3.4%, the 2006 bowhead population may number around 12,500 animals. The large increases in population estimates that occurred from the late 1970s to the early 1990s were partly a result of actual population growth, but were also partly attributable to improved census techniques (Zeh et al. 1993). Although apparently recovering well, the BCB bowhead population is currently listed as "***Endangered***" under the ESA and is classified as a ***strategic stock*** by NMFS (Angliss and Lodge 2002).

Most spring-migrating bowhead whales will likely pass through the Chukchi and Beaufort seas prior to the start of the survey in mid-June. However, a few whales that may remain in the Chukchi Sea or in the Barrow area during the summer could be encountered during the cruise. More encounters with bowhead whales would occur in the Chukchi Sea during the westward fall migration in September and October. The migration pathway spilts and animals become more dispered upon entering the Chukchi Sea from the Beaurfort Sea, so encounters are expected to be much lower than if operation were planned in the Beaufort Sea. GXT plans to operate at a great distance from the subsistence hunt at Barrow, if it is still ongoing when the vessel returns to the Chukchi Sea.

(b) Gray Whale (*Eschrichtius robustus*)

Gray whales originally inhabited both the North Atlantic and North Pacific oceans. The Atlantic populations are believed to have become extinct by the early 1700s. There are two populations in the North Pacific. A relic population which survives in the Western Pacific summers near Sakhalin Island far from the proposed survey area. The larger eastern Pacific or California gray whale population recovered significantly from commercial whaling during its protection under the ESA until 1994 and numbered about 26,635 in 1998 (Rugh et al. 1999; Angliss and Lodge 2002; NMFS 2002). However, abundance estimates since 1998 indicate a consistent decline, and Rugh (2003 *in* Keller and Gerber 2004; see also Rugh et al. 2005) estimated the population to be 17,500 in 2002. The eastern Pacific stock is not considered by NMFS to be endangered or to be a strategic stock.

Eastern Pacific gray whales breed and calve in the protected waters along the west coast of Baja California and the east coast of the Gulf of California from January to April (Swartz and Jones 1981; Jones and Swartz 1984). At the end of the breeding and calving season, most of these gray whales migrate about 8000 km, generally along the west coast of North America, to the main summer feeding grounds in the northern Bering and Chukchi seas (Tomilin 1957; Rice and Wolman 1971; Braham 1984; Nerini 1984).

Most summering gray whales have historically congregate in the northern Bering Sea, particularly off St. Lawrence Island in the Chirikov Basin (Moore et al. 2000a), and in the southern Chukchi Sea. More recently, Moore et al. (2003) suggested that gray whale use of Chirikov Basin has decreased, likely as a result of the combined effects of changing currents resulting in altered secondary productivity dominated by lower quality food. The northeastern-most of the recurring feeding areas is in the northeastern Chukchi Sea southwest of Barrow (Clarke et al. 1989). Gray whales feed by suctioning sediment and filtering benthic invertebrates from the sediment with their short, coarse baleen (Moore et al. 2000b).

Gray whales routinely feed in the Chukchi Sea during the summer. Moore et al. (2000b) reported that during the summer, gray whales in the Chukchi Sea were clustered along the shore primarily between Cape Lisburne and Point Barrow and were associated with shallow, coastal shoal habitat. In autumn, gray whales were clustered near shore at Point Hope and between Icy Cape and Point Barrow, as well as in offshore waters northwest of Point Barrow at Hanna Shoal and southwest of Point Hope. Gray whales occur fairly often near Point Barrow, but historically only a small number of gray whales have been sighted in the Beaufort Sea east of Point Barrow.

Gray whales may be encountered during the Chukchi Sea seismic survey. Although they are most common close to shore (where GXT plans no seismic work), gray whales may also occur in offshore areas of the Chukchi Sea later in the summer.

(c) Minke Whale (*Balaenoptera acutorostrata*)

Minke whales have a cosmopolitan distribution at ice-free latitudes (Stewart and Leatherwood 1985), and also occur in some marginal ice areas. Angliss and Lodge (2004) recognize two minke whale stocks in U.S. waters: (1) the Alaska stock, and (2) the California/Oregon/Washington stock. There is no abundance estimate for the Alaska stock. Provisional estimates of minke whale abundance based on surveys in 1999 and 2000 are 810 and 1003 whales in the central-eastern and south-eastern Bering Sea, respectively. These estimates have not been corrected for animals that may have been submerged or otherwise missed during the surveys, and only a portion of the range of the Alaskan stock was surveyed. The minke whale range into the Chukchi Sea, but the level of minke whale use of the Chukchi Sea is unknown. Leatherwood et al. (1982, *in* Angliss and Lodge 2004) indicated that minke whales are not considered abundant in any part of their range, but that some individuals venture north of the Bering Strait in summer. Minke whales could be encountered during the cruise in the Chukchi Sea.

(d) Fin Whale (*Balaenoptera physalus*)

Fin whales are widely distributed in all the world's oceans (Gambell 1985), but typically occur in temperate and polar regions. Fin whales feed in northern latitudes during the summer where their prey includes plankton as well as shoaling pelagic fish, such as capelin *Mallotus villosus* (Jonsgård 1966a,b). The North Pacific population summers from the Chukchi Sea to California (Gambell 1985), but does not range into the Alaskan Beaufort Sea or waters of the northern Chukchi Sea. Population estimates for the entire North Pacific population range from 14,620 to 18,630. Reliable estimates of fin whale abundance in the Northeast Pacific are not available (Angliss and Lodge 2004). Provisional estimates of fin whale abundance in the central-eastern and south-eastern Bering Sea are 3,368 and 683, respectively. No estimates for fin whale abundance during the summer in the Chukchi Sea are available and few are expected to be encountered. The fin whale is listed as "***Endangered***" under the ESA and by IUCN, is classified as a ***strategic stock*** under the MMPA and by NMFS, and is a CITES Appendix I species (Table 2).

(3) Pinnipeds

(a) Pacific Walrus (*Odobenus rosmarus divergens*)

Walruses occur in moving pack ice over shallow waters of the circumpolar Arctic coast (King 1983). There are two recognized subspecies of walrus: the Pacific and Atlantic walrus (*O. r. rosmarus*). Only the Pacific subspecies is potentially within the planned seismic survey study area. GXT has submitted to USFWS a separate IHA Application concerning walruses (and polar bears) in the Chukchi Sea.

Walruses are abundant in the Chukchi Sea and will likely be encountered during the cruise. During a survey through the northern Chukchi Sea in early August of 2005, three walruses were sighted; none were further north than 72.8°N (Haley and Ireland 2006). Walruses are most likely to be encountered where water depth is relatively shallow (i.e., <80 m). Besides depending on water depth, the probability of encountering Pacific walruses along the proposed trackline will depend on the location of the southern edge of the pack ice and the timing of spring break-up.

(b) Bearded Seal (*Erignathus barbatus*)

Bearded seals are associated with sea ice and have a circumpolar distribution (Burns 1981). During the open-water period, bearded seals occur mainly in relatively shallow areas, because (like the walrus) they are predominantly benthic feeders (Burns 1981). They prefer areas of water no deeper than 200 m (e.g., Harwood et al. 2005).

In Alaskan waters, bearded seals occur over the continental shelves of the Bering, Chukchi, and Beaufort seas (Burns 1981). The Alaska stock of bearded seals may consist of about 300,000–450,000 individuals (MMS 1996). Results of aerial surveys of the eastern Chukchi Sea indicated densities of up to 0.149 bearded seals per km^2 and a population of 4862 animals, although actual abundance may be much higher (Anglis and Lodge 2004). The Alaska stock of bearded seals is not classified by NMFS as endangered or a strategic stock.

The bearded seal is the largest of the northern phocids. Bearded seals have occasionally been reported to maintain breathing holes in sea ice and broken areas within the pack ice, particularly if the water depth is <200 m. Bearded seals apparently also feed on ice-associated organisms when they are present, and this allows a few bearded seals to live in areas considerably more than 200 m deep.

Seasonal movements of bearded seals are directly related to the advance and retreat of sea ice and to water depth (Kelly 1988). During winter, most bearded seals in Alaskan waters are found in the Bering Sea. In the Chukchi Sea, favorable conditions are more limited, and consequently, bearded seals are less abundant there during winter. From mid-April to June, as the ice recedes, some of the bearded seals that overwintered in the Bering Sea migrate northward through the Bering Strait. During the summer they are found near the widely fragmented margin of multi-year ice covering the continental shelf of the Chukchi Sea.

In some areas, bearded seals are associated with the ice year-round; however, they usually move shoreward into open water areas when the pack ice retreats to areas with water depths greater than 200 m. During the summer, when the Bering Sea is ice-free, the most favorable bearded seal habitat is found in the central or northern Chukchi Sea along the margin of the pack ice. Bearded seal densities in the pack ice of the northern Chukchi see appear to be low as only three bearded seals were observed during a survey that passed through the proposed seismic survey area in early August of 2005 (Haley and Ireland 2006).

(c) Spotted Seal (*Phoca largha*)

Spotted seals (also known as largha seals) occur in the Beaufort, Chukchi, Bering and Okhotsk seas, and south to the northern Yellow Sea and western Sea of Japan (Shaughnessy and Fay 1977). They migrate south from the Chukchi Sea and through the Bering Sea in October (Lowry et al. 1998). Spotted seals overwinter in the Bering Sea and inhabit the southern margin of the ice during spring (Shaughnessy and Fay 1977).

An early estimate of the size of the world population of spotted seals was 370,000–420,000, and the size of the Bering Sea population, including animals in Russian waters, was estimated to be 200,000–250,000 animals (Bigg 1981). The total number of spotted seals in Alaskan waters is not known (Angliss and Lodge 2002), but the estimate is most likely between several thousand and several tens of thousands (Rugh et al. 1997). During the summer spotted seals are found in Alaska from Bristol Bay through western Alaska to the Chukchi and Beaufort seas. The ADF&G placed satellite transmitters on 4 spotted seals in Kasegaluk Lagoon and estimated that the proportion of seals hauled out was 6.8%. Based on an actual minimum count of 4145 hauled out seals, Angliss and Lodge (2004) estimated the Alaskan population at 59,214 animals. The Alaska stock of spotted seals is not classified as endangered or as a strategic stock by NMFS (Hill and DeMaster 1998).

During spring when pupping, breeding, and molting occur, spotted seals are found along the southern edge of the sea ice in the Okhotsk and Bering seas (Quakenbush 1988; Rugh et al. 1997). In late April and early May, adult spotted seals are often seen on the ice in female-pup or male-female pairs, or in male-female-pup triads. Subadults may be seen in larger groups of up to two hundred animals. During the summer, spotted seals are found primarily in the Bering and Chukchi seas, but some range into the Beaufort Sea (Rugh et al. 1997; Lowry et al. 1998) from July until September. At this time of year, spotted seals haul out on land part of the time, but also spend extended periods at sea. The seals are commonly seen in bays, lagoons and estuaries, but also range far offshore as far north as 69–72ºN. In summer, they are rarely seen on the pack ice, except when the ice is very near to shore. As the ice cover thickens with the onset of winter, spotted seals leave the northern portions of their range and move into the Bering Sea (Lowry et al. 1998).

In the Chukchi Sea, Kasegaluk Lagoon is an important area for spotted seals. Spotted seals haul out in the area from mid-July until freeze-up in late October or November. Frost and Lowry (1993) reported a maximum count of about 2200 spotted seals in the lagoon during aerial surveys. No spotted seals were recorded along the shore south of Pt. Lay. Based on satellite tracking data, Frost and Lowry (1993) reported that spotted seals at Kasegaluk Lagoon spent 94% of the time at sea. Extrapolating the count of hauled-out seals to account for seals at sea would suggest a Chukchi Sea population of about 36,000 animals.

(d) Ringed Seal (*Pusa hispida*)

Ringed seals have a circumpolar distribution and occur in all seas of the Arctic Ocean (King 1983). They are closely associated with ice, and in the summer they often occur along the receding ice edges or farther north in the pack ice. In the North Pacific, they occur in the southern Bering Sea and range south to the seas of Okhotsk and Japan. They are found throughout the Beaufort, Chukchi, and Bering seas (Angliss and Lodge 2004).

During winter, ringed seals occupy landfast ice and offshore pack ice of the Bering, Chukchi and Beaufort seas. In winter and spring, the highest densities of ringed seals are found on stable shorefast ice. However, in some areas where there is limited fast ice but wide expanses of pack ice, including the Beaufort Sea, Chukchi Sea and Baffin Bay, total numbers of ringed seals on pack ice may exceed those on shorefast ice (Burns 1970; Stirling et al. 1982; Finley et al. 1983). Ringed seals maintain breathing holes in the ice and occupy lairs in accumulated snow (Smith and Stirling 1975). They give birth in lairs from mid-March through April, nurse their pups in the lairs for 5–8 weeks, and mate in late April and May (Smith 1973; Hammill et al. 1991; Lydersen and Hammill 1993).

Ringed seals are year-round residents in the northern Chukchi Sea and the most frequently encountered seal species in the area. No estimate for the size of the Alaska ringed seal stock is currently available (Angliss and Lodge 2002). Past ringed seal population estimates in the Bering-Chukchi-Beaufort area ranged from 1–1.5 million (Frost 1985) to 3.3–3.6 million (Frost et al. 1988). The Alaska stock of ringed seals is not endangered, and is not classified as a strategic stock by NMFS. Bengtson et al. (2005) reported corrected ringed seal densities of 1.91 seals per km^2 in the eastern Chukchi Sea during aerial surveys in May and June of 1999 and 2000. Densities were higher in nearshore than offshore locations, and nearshore waters will not be surveyed during this project. The corrected ringed seal densities on the pack ice offshore from Shishmaref to Barrow, averaged from 1999 and 2000 aerial survey data from Bengtson et al. (2005), is 0.935 seals/km^2. Bengtson et al. (2005) estimated the total Chukchi Sea population at 245,048 animals.

Marine mammal observers aboard the *Healy* sighted as many as 50 ringed seals along 2401 km of trackline between 70°N and 81°N during two weeks of travel in and north of the Chukchi Sea during August 2005 (Haley and Ireland 2006). Ringed seals will likely be encountered during both the Beaufort and Chukchi portions of the cruise.

(4) Carnivora

(a) Polar Bear (*Ursus maritimus*)

Polar bears have a circumpolar distribution throughout the northern hemisphere (Amstrup et al. 1986) and occur in relatively low densities throughout most ice-covered areas (DeMaster and Stirling 1981). GXT has submitted to USFWS a separate IHA Application concerning polar bears (and walruses) in the Chukchi Sea. During the proposed survey, polar bears are likely to be encountered near the pack ice. However, small numbers of bears could be encountered anywhere along the entire trackline.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

The type of incidental taking authorization that is being requested (i.e., takes by harassment only, takes by harassment, injury and/or death), and the method of incidental taking.

GXT requests an IHA pursuant to Section 101(a)(5)(D) of the MMPA for incidental take by harassment during its planned geophysical survey in the Chukchi Sea during June–November 2006.

The operations outlined in § I and II have the potential to take marine mammals by harassment. Sounds that may "harass" marine mammals will be generated by the 36-airgun array used during the survey. "Takes" by harassment will potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the airguns or sonars. The effects will depend on the species of cetacean or pinniped, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals in the general vicinity of the tracklines of the source vessel. No take by serious injury is anticipated, given the nature of the planned operations and the mitigation measures that are planned (see § XI, "Mitigation Measures"). No lethal takes are expected.

VI. NUMBERS OF MARINE MAMMALS THAT MAY BE TAKEN

By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in [section V], and the number of times such takings by each type of taking are likely to occur.

The material for Sections VI and VII has been combined and presented in reverse order to minimize duplication between sections.

VII. Anticipated Impact on Species or Stocks

The anticipated impact of the activity upon the species or stock of marine mammal.

The material for Sections VI and VII has been combined and presented in reverse order to minimize duplication between sections.

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in Section VII. A more comprehensive review of the relevant background information appears in Appendix C.
- Then we discuss the potential impacts of operations by a pinger system.
- Finally, we estimate the numbers of marine mammals that might be affected by the proposed activity in the Chukchi Sea June–November 2006. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in Section VI.

(a) Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical effects (Richardson et al. 1995). It is unlikely that there would be any cases of temporary or especially permanent hearing impairment, or non-auditory physical effects.

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. For a summary of the characteristics of airgun pulses, see Appendix C (c). Numerous studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response—see Appendix C (e). That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds, small odontocetes, and sea otters seem to be more tolerant of exposure to airgun pulses than are baleen whales.

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data of relevance. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a more recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). That has also been shown during recent work in the Gulf of Mexico (Tyack et al. 2003). Bowhead whale calls are frequently detected in the presence of seismic pulses, although the number of calls detected may sometimes be reduced in the presence of airgun pulses (Richardson et al. 1986; Greene et al. 1999). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses. Also, the sounds important to small odontocetes are predominantly at much higher frequencies than are airgun sounds. Masking effects, in general, are discussed further in Appendix C (d).

Disturbance Reactions

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Based on NMFS (2001, p. 9293), we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be significant. Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. That likely overestimates the numbers of marine mammals that are affected in some biologically-important manner.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray, and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, small toothed whales, and sea otters.

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, as reviewed in Appendix C (e), baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the case of the migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 μPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4.5 to 14.5 km from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong disturbance reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and recent studies reviewed in Appendix C (e) have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa rms. Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a mediumsized airgun source (Miller et al. 1999; Richardson et al. 1999; see Appendix C [e]). However, more recent research on bowhead whales (Miller et al. 2005) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. In summer, bowheads typically begin to show avoidance reactions at a received level of about 160–170 dB re 1 μPa rms (Richardson et al. 1986; Ljungblad et al. 1988; Miller et al. 1999). The GXT project is to be partly in summer, when feeding bowheads might be encountered (although the primary bowhead summer feeding grounds are far to the east in the Canadian Beaufort Sea), and partly in autumn, when the bowheads are commonly involved in migration (though bowheads also continue to feed in autumn).

Malme et al. (1986, 1988) studied the responses of feeding eastern gray whales to pulses from a single 100 in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast, and on observations of Western Pacific gray whales feeding off Sakhalin Island, Russia (Johnson 2002).

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration and much ship traffic in that area for decades (Appendix A *in* Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987). Populations of both gray whales and bowhead whales grew substantially during this time. In any event, the brief exposures to sound pulses from the proposed airgun source are highly unlikely to result in prolonged effects.

Toothed Whales.—Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above and (in more detail) in Appendix C have been reported for toothed whales. However, systematic work on sperm whales is underway (Tyack et al. 2003), and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004; Moulton and Miller in press).

Seismic operators and marine mammal observers sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of seismic vessels operating large airgun systems. However, some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when large arrays of airguns are firing. Nonetheless, there have been indications that small toothed whales sometimes move away, or maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Goold 1996a,b,c; Calambokidis and Osmek 1998; Stone 2003). The beluga may be a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys during seismic operations in the southeastern Beaufort Sea recorded much lower sighting rates of beluga whales within 10–20 km of an active seismic vessel. These results were consistent with the low number of beluga sightings reported by observers aboard the seismic vessel, suggesting that some belugas might be avoiding the seismic operations at distances of 10–20 km (Miller et al. 2005).

Captive bottlenose dolphins and (of more relevance in this project) beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2002, 2005). However, the animals tolerated high received levels of sound (pk–pk level >200 dB re 1 µPa) before exhibiting aversive behaviors. With the presently-planned source, such levels would be limited to distances less than 200 m of the 36-airgun array in shallow water. The reactions of belugas to the GXT survey are likely to be more similar to those of free-ranging belugas exposed to airgun sound (Miller et al. 2005) than to those of captive belugas exposed to a different type of strong transient sound (Finneran et al. 2000, 2002).

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for mysticetes (Apppendix C). A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids (and pinnipeds), which tend to be less responsive than other cetaceans. However, based on the limited existing evidence, belugas should not be grouped with delphinids in the "less responsive" category.

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to the airgun sources that will be used. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix C (e). Ringed seals frequently do not avoid the area within a few hundred meters of operating airgun arrays (Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). However, initial telemetry work suggests that avoidance and other behavioral reactions by two other species of seals to small airgun sources may at times be stronger than evident to date from visual studies of pinniped reactions to airguns (Thompson et al. 1998). Even if reactions of the species occurring in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations. As for delphinids, a ≥170 dB disturbance criterion is considered appropriate for pinnipeds, which tend to be less responsive than many cetaceans.

Polar Bears.—Airgun effects on polar bears have not been studied. However, polar bears on the ice would be unaffected by underwater sound. Sound levels received by polar bears in the water would be attenuated because polar bears generally do not dive much below the surface. Received levels of airgun sounds are reduced near the surface because of the pressure release effect at the water's surface (Greene and Richardson 1988; Richardson et al. 1995).

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, but there has been no specific documentation of this for marine mammals exposed to sequences of airgun pulses. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds ≥180 and ≥190 dB re 1 µPa (rms), respectively (NMFS 2000). Those criteria have been used in defining the safety (shut down) radii planned for the proposed seismic survey. However, those criteria were established before there were any data on the minimum received levels of sounds necessary to cause temporary auditory impairment in marine mammals. As discussed in Appendix C (f) and summarized here,

- the 180 dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid temporary threshold shift (TTS), let alone permanent auditory injury, at least for belugas and delphinids.
- the minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.

- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage.

NMFS is presently developing new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS and other relevant factors in marine and terrestrial mammals (NMFS 2005; D. Wieting *in* http://mmc.gov/sound/plenary2/pdf/plenary2summaryfinal.pdf).

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airguns to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment [see § II(3), MITIGATION MEASURES]. In addition, many cetaceans are likely to show some avoidance of the area with high received levels of airgun sound (see above). In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects might also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that theoretically might occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds. However, as discussed below, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns and beaked whales do not occur in the present study arae. It is unlikely that any effects of these types would occur during the present project given the brief duration of exposure of any given mammal, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, permanent threshold shift (PTS), and non-auditory physical effects.

Temporary Threshold Shift (TTS).—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. At least in terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity in both terrestrial and marine mammals recovers rapidly after exposure to the noise ends. Few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound.

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Given the available data, the received level of a single seismic pulse might need to be ~210 dB re 1 μPa rms (~221–226 dB pk–pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 200 m around a seismic vessel operating a large array of airguns.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. However, no cases of TTS are expected given the moderate size of the source, and the strong likelihood that baleen whales (especially migrating bowheads) would avoid the approaching airguns (or vessel) before being exposed to levels high enough for there to be any possibility of TTS.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from prolonged exposures suggested that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001; cf. Au et al. 2000). In the harbor seal, which is closely related to the ringed seal, TTS onset apparently occurs at somewhat lower received energy levels than for odontocetes [see Appendix C (f)].

A marine mammal within a radius of ≤100 m (≤328 ft) around a typical large array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel. (As noted above, most cetacean species tend to avoid operating airguns, although not all individuals do so.) However, several of the considerations that are relevant in assessing the impact of typical seismic surveys with arrays of airguns are not directly applicable here:

- "Ramping up" (soft start) is standard operational protocol during startup of large airgun arrays in many jurisdictions. Ramping up involves starting the airguns in sequence, usually commencing with a single airgun and gradually adding additional airguns. This practice will be employed when either airgun array is operated.
- It is unlikely that cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal.
- With a large array of airguns, TTS would be most likely in any odontocetes that bow-ride or in any odontocetes or pinnipeds that linger near the airguns. In the present project, GXT anticipates the 190 and 180 dB distances in intermediate-depth water to be 60 m and 250 m, respectively, for the 36-airgun gun array (Table 2). The waterline at the bow of the *Discoverer* will be ~80 m ahead of the airguns. However, no species that occur within the project area are expected to bow-ride.
- There is a possibility that a small number of seals (which often show little or no avoidance of approaching seismic vessels) could occur close to the airguns and that they might incur slight TTS if no mitigation action (shutdown) were taken.

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 μPa (rms). The 180 and 190 dB distances for the airguns operated by GXT may be found to vary with water depth once acoustic verification and possibly further pre-season acoustic modeling have been completed. However, estimates most applicable to intermediate depth water have been listed (Table 1) until those results are available. The 190 and 180 dB radii are estimated by GXT to be 60 m and 250 m, respectively. Precautionary (×1.5) shutdown distances are proposed to be used until these radii can be verified empirically. The 180 and 190 dB re 1 μPa (rms) safety radii will be revised when results are available from possible pre-field-season modeling and from acoustic verification to be conducted early in the seismic survey. Furthermore, established 190 and 180 dB re 1 μPa (rms) "do not exceed" criteria are ***not*** considered to be the levels above which TTS might occur. Rather, they are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above, data that are now available imply that TTS is unlikely to occur unless odontocetes are exposed to airgun pulses much stronger than 180 dB re 1 μPa rms. Since no bow-riding species occur in the study area, it is unlikely such exposures will occurr.

Permanent Threshold Shift (PTS).—When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that mammals close to an airgun array might incur TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level at least several decibels above that inducing mild TTS if the animal were exposed to the strong sound pulses with very rapid rise time—see Appendix C (f).

It is highly unlikely that marine mammals could receive sounds strong enough (and over a sufficient duration) to cause permanent hearing impairment during a project employing the airgun sources planned here. In the proposed project, marine mammals are unlikely to be exposed to received levels of seismic pulses strong enough to cause more than slight TTS. Given the higher level of sound necessary to cause PTS, it is even less likely that PTS could occur. In fact, even the levels immediately adjacent to the airgun may not be sufficient to induce PTS, especially because a mammal would not be exposed to more than one strong pulse unless it swam immediately alongside the airgun for a period longer than the inter-pulse interval. Baleen whales, and apparently belugas as well, generally avoid the immediate area around operating seismic vessels. The planned monitoring and mitigation measures, including visual monitoring, power downs, and shut downs of the airguns when mammals are seen within the "safety radii", will minimize the already-minimal probability of exposure of marine mammals to sounds strong enough to induce PTS.

Non-auditory Physiological Effects.— Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, and other types of organ or tissue damage. However, studies examining such effects are very limited. If any such effects do occur, they probably would be limited to unusual situations when animals might be exposed at close range for unusually long periods. It is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop. That is especially so in the case of the proposed project where the airgun configuration focuses most energy downward, the ship is moving at 4–5 knots, and for the most part, the tracklines will not "double back" through the same area.

Until recently, it was assumed that diving marine mammals are not subject to the bends or air embolism. This possibility was first explored at a workshop (Gentry [ed.] 2002) held to discuss whether the stranding of beaked whales in the Bahamas in 2000 (Balcomb and Claridge 2001; NOAA and USN 2001) might have been related to bubble formation in tissues caused by exposure to noise from naval sonar. However, the opinions were inconclusive. Jepson et al. (2003) first suggested a possible link between mid-frequency sonar activity and acute and chronic tissue damage that results from the formation *in vivo* of gas bubbles, based on the beaked whale stranding in the Canary Islands in 2002 during naval exercises. Fernández et al. (2005a) showed those beaked whales did indeed have gas bubble-associated lesions as well as fat embolisms. Fernández et al. (2005b) also found evidence of fat embolism in three beaked whales that stranded 100 km north of the Canaries in 2004 during naval exercises. Examinations of several other stranded species have also revealed evidence of gas and fat embolisms (e.g., Arbelo et al. 2005; Jepson et al. 2005a; Méndez et al. 2005). Most of the afflicted species were deep divers. There is speculation that gas and fat embolisms may occur if cetaceans ascend unusually quickly when exposed to aversive sounds, or if sound in the environment causes the destabilization of existing bubble nuclei (Potter 2004; Arbelo et al. 2005; Fernández et al. 2005a; Jepson et al. 2005b). Even if gas and fat embolisms can occur during exposure to mid-frequency sonar, there is no evidence that that type of effect occurs in response to airgun sounds. Also, most evidence for such effects have been in beaked whales, which do not occur in the proposed study area.

In general, little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances and probably to projects involving large arrays of airguns. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in those ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes (including belugas), and some pinnipeds, are especially unlikely to incur auditory impairment or other physical effects. Also, the planned monitoring and mitigation measures include shut downs of the airguns, which will reduce any such effects that might otherwise occur.

Strandings and Mortality

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of mass strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey, has raised the possibility that beaked whales exposed to strong pulsed sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding. Appendix C (g) provides additional details.

Seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by airgun arrays are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time. Thus, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar pulses can, in special circumstances, lead to physical damage and mortality (Balcomb and Claridge 2001; NOAA and USN 2001; Jepson et al. 2003; Fernández et al. 2005a), even if only indirectly, suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

In Sept. 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel *Maurice Ewing* was operating a 20-airgun, 8490 in^3 array in the general area. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). Nonetheless, that plus the incidents involving beaked whale strandings near naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales. However, no beaked whales are found within this project area and the planned monitoring and mitigation measures are expected to minimize any possibility for mortality of other species.

(b) Possible Effects of Pinger Signals

A pinger system (DigiRANGE I and II, Input/Output, Inc.) will be used during seismic operations to position the airgun array and hydrophone streamer relative to the vessel. Sounds from the pingers are very short pulses, occurring for 10 ms, with source level ~180 dB re 1 μPa·m at 55 kHz, ~188 dB re μPa·m at 75 kHz, and ~184 dB re 1 μPa·m at 95 kHz. One pulse is emited on command from the operator aboard the source vessel, which under normal operating conditions is once every ~10 s. Most of the energy in the sound pulses emitted by this pinger is at very high frequencies between 50 and 100 kHz. The signal is omnidirectional.

The pinger produces sounds that are above the range of frequencies produced or heard by many of the marine mammals expected to occur in the study area. However, the beluga whale produces echolocation sounds (clicks) within the 50–100 kHz range (Au et al. 1985, 1987; Au 1993), and belugas have good hearing sensitivity across this ultrasonic frequency band (White et al. 1978; Johnson et al. 1989). In the event that killer whales or harbor porpoises are encountered, they could also hear the pinger signals. Some seals also can hear sounds at frequencies up to somewhat above 55 kHz. (See §8.2 *in* Richardson et al. [1995] for a review of cetacean and pinniped hearing capabilities.) Neither baleen whales nor walruses would hear sounds at and above 55 kHz (for walrus, see Kastelein et al. 2002).

Masking

The pinger produces sounds within the frequency range used by belugas and other odontocetes that may be present in the survey area. Some seals also can hear sounds at frequencies up to somewhat above 55 kHz. (See §8.2 *in* Richardson et al. [1995] for a review of cetacean and pinniped hearing capabilities.) However, marine mammal communications will not be masked appreciably by the pinger signals. This is a consequence of the relatively low power output, low duty cycle, and brief period when an individual mammal is likely to be within the area of potential effects. Also, in the case of seals, the pulses do not overlap with the predominant frequencies in the calls, which would avoid significant masking. Baleen whales would not hear sounds at and above 55 kHz so the pinger would have no effect on them.

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the pinger are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the pinger are much weaker than those from the airgun. Therefore, behavioral responses are not expected unless marine mammals are very close to the source. In this project, odontocetes and seals are the types of marine mammals that might hear the pings if these animals were close to the source. The maximum reaction that might be expected would be a startle reaction or other short-term response. NMFS (2001) has concluded that momentary behavioral reactions “do not rise to the level of taking”.

Hearing Impairment and Other Physical Effects

Source levels of the pinger are much lower than those of the airguns, which are discussed above. It is unlikely that the pinger produces pulse levels strong enough to cause temporary hearing impairment or (especially) physical injuries even in an animal that is (briefly) in a position near the source.

(c) Numbers of Marine Mammals that Might be “Taken by Harassment”

All anticipated takes would be “takes by harassment”, as described in § V, involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier and in Appendix C, there is no specific information demonstrating that injurious “takes” would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate “take by harassment” and present estimates of the numbers of marine mammals that might be affected during the proposed seismic study in the Chukchi Sea. The estimates are based on data obtained during marine mammal surveys in and near the proposed survey area and on estimates of the sizes of the areas where effects could potentially occur. In some cases, these estimates were made from data collected in regions, habitats, or seasons that differ from the activities in the proposed survey. Adjustments to reported population or density estimates were made to account for these differences insofar as possible.

This section provides estimates of the number of potential "exposures" to sound levels ≥160 and/or ≥170 dB re 1 μPa (rms). The ≥160 dB criterion is applied for all species of cetaceans and pinnipeds; the ≥170 dB criterion is applied for delphinids and pinnipeds. Based on evidence summarized in § VII(a) and Appendix C, the 170 dB criterion is considered appropriate for those two groups, which tend to be less responsive, whereas the 160 dB criterion is considered relevant for other cetaceans. Evidence indicates that the 160 dB criterion is suitable for summering bowhead whales (Richardson et al. 1986; Miller et al. 2005). However, during autumn some migrating bowheads in the Beaufort Sea have been found to react to a noise threshold closer to 130 dB re 1 μPa (rms; Miller et al. 1999; Richardson et al. 1999).

Although several systematic surveys of marine mammals have been conducted in the southern Beaufort Sea, few data (systematic or otherwise) are available on the distribution and numbers of marine mammals in the Chukchi Sea. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection. There is some uncertainty about the representativeness of those data and the assumptions used below to estimate the potential "take by harassment". However, the approach used here seems to be the best available at this time.

The following estimates are based on a consideration of the number of marine mammals that might be disturbed appreciably by ~5302 line kilometers of seismic surveys across the Chukchi Sea. An assumed total of 6628 km of trackline in the Chukchi Sea includes a 25% allowance over and above the planned trackline to allow for turns and lines that might have to be repeated because of poor data quality, or for minor changes to the survey design.

The anticipated radii of influence of the pinger system are (for the species that could hear it) much less than those for the airgun array. It is assumed that, during simultaneous operations of the arigun array and pinger system, any marine mammals close enough to be affected by the pingers would already be affected by the airguns. However, whether or not the airguns are operating simultaneously with the pinger system, odontocetes and seals are expected to exhibit no more than short-term and inconsequential responses to the pingers given their characteristics as described in § I and in § VII(b,c) above. Such reactions are not considered to constitute "taking" (NMFS 2001). Therefore, no additional allowance is included for animals that might be affected by sound sources other than the airguns.

Basis for Estimating "Take by Harassment" for the Beaufort Sea Seismic Survey

Numbers of marine mammals that might be present and potentially disturbed are estimated below based on available data about mammal distribution and densities at different locations and times of the year. The proposed survey covers a large area in the Chukchi Sea in two different seasons. The estimates of marine mammal densities have therefore been separated both spatially and temporaraly in an attempt to represent the distribution of animals expected to be encountered over the duration of the survey.

Density estimates in the Chukchi Sea have been derived for two time periods, the early summer period covering the months of June and July, and the late fall period including most of October and November (see § II for a detailed description of the proposed activities). Animal densities encountered in the Chukchi Sea during both of these time periods will depend on the habitat zone within which the vessel is operating: (1) open water, or (2) ice margin. The *Discoverer* is not an ice breaker. Therefore, it will not operate in water with >30% ice cover and will generally be limited to areas of truly open water. Under this assumption, densities of marine mammals expected to be observed in or near ice margin areas have been applied to 15% of the proposed survey trackline. Densities of marine mammals expected to occur in open-water areas have been applied to the remaining 85% of the survey trackline.

Approximately 1/3rd of the proposed Chukchi Sea trackline is planned to be completed in June and July so the summer density estimates have been applied to 1/3rd of the trackline falling within each habitat zone. The other 2/3rd of the trackline is planned to be surveyed in October and November, so the fall marine mammal densities have been applied to the remainder of the trackline in each habitat zone.

For the Chukchi Sea, cetacean densities during the summer were estimated from effort and sighting data in Moore et al. (2000b) and Richardson and Thomson (eds., 2002) while pinniped densities were estimated from Bengtson (2005) and Moulton and Lawson (2002). (Some of those references concerned surveys in the Beaufort Sea rather than the Chukchi, but were considered relevant to the Chukchi as well or the best available data.) Because few data are available on the densities of marine mammals in the Chukchi Sea in the fall, density estimates from the summer and spring have been adjusted to reflect the expected ratio of summer-to-fall densities based on the natural history characteristic of each species.

There is some uncertainty about the representativeness of the data and assumptions used in the calculations. To provide some allowance for the uncertainties, “maximum estimates” as well as “average estimates” of the numbers potentially affected have been derived. For a few marine mammal species, several density estimates were available, and in those cases, the mean and maximum estimates were from the survey data. In other cases only one, or no applicable estimate was available so arbitrary correction factors were used to arrive at “average” and “maximum” estimates. These are described in the following sections. Except where noted, the “maximum” estimates have been calculated as 4× the “average” estimates. The densities presented are believed to be similar to, or in most cases higher than, the densities that will actually be encountered during the survey.

Detectability bias, quantified in part by $f(0)$, is associated with diminishing sightability with increasing lateral distance from the trackline. Availability bias [$g(0)$] refers to the fact that there is <100% probability of sighting an animal that is present along the survey trackline. These correction factors were applied to the data for all species from the three primary sources, Moore et al. (2000b), Richardson and Thomson (eds., 2002), and Bengtson et al. (2005), accept for bearded seals.

Chukchi Sea

Estimated densities of marine mammals in the Chuckhi Sea project area during the summer (June and July) are presented in Table 3. Densities of marine mammals estimated for the autumn period of GXT’s seismic operations in the Chukchi Sea (October and November) are presented in Table 4. Again, “average” and “maximum” densities are shown in the tables. Unless otherwise noted, maximum densities are 4× average densities.

Cetaceans

Eight species of cetaceans are known to occur in the Chukchi Sea area of the proposed GXT project. Only three of these (bowhead, beluga, and gray whale) are expected to be encountered in meaningful numbers during the proposed survey.

Summer and autumn densities of ***beluga whales*** were estimated from the summer surveys of Moore et al. (2000b) in the Alaskan Beaufort Sea, north and east of the proposed Chukchi Sea survey area. Belugas are typically found along the coast, e.g., near Kasegaluk Lagoon (Suydam et al. 2001) in the summer. It is unlikely that belugas will be encountered in the open water and ice margin areas during summer in the Chukchi Sea; densities in those areas were set to arbitrary minimal estimates (Table 3).

In the fall, beluga whales are expected to be found in highest densities in the open water of the Chukchi Sea. Individuals of the Beaufort Sea stock will be migrating to their wintering grounds in the Bering Sea in the autumn (Angliss and Lodge 2002). Densities of the traveling animals are therefore predicted to be higher in open water than in the ice margin area. Densities from Moore et al. (2000b) from surveys in the Beaufort Sea were adjusted by a factor of ×0.125 for the open water autumn estimate, and by ×0.0125 for the ice margin area (Table 4).

Bowhead whale estimates for the Chukchi Sea were calculated from Richardson and Thomson (eds., 2002). By July, most bowhead whales are northeast of the Chukchi Sea, within or migrating toward their summer feeding grounds in the eastern Beaufort Sea. For summer, the bowhead whale densities in both habitat zones of the Chukchi Sea were estimated as 0.01× the summer densities observed by Richardson and Thomson (eds., 2002; Table 3), given that numbers in the Chukchi are expected to be very low during the summer (Moore et al. 2006). During the autumn, bowhead whales are migrating west and south to their wintering grounds in the Bering Sea making it more likely that they would be encountered in the Chukchi Sea. However, seismic survey activities are planned to continue in the Canadian Beaufort Sea as late into the fall as ice conditions allow, meaning that most bowhead whales will likely be west of the Chukchi Sea survey area when the seismic survey resumes there in the fall. (In autumn, most bowheads travel to Russian waters north of the Chukotsk Peninsula.) Thus, a correction factor of ×0.05 has been used to adjust the observed autumn densities from the Beaufort Sea (Richardson and Thomson 2002; Table 4), where the migration corridor is narrow, to estimated densities in the Chukchi Sea, where the migration corridor becomes bifurcated and much broader.

Gray whale densities were also estimated from summer surveys by Moore et al. (2000b). Moore et al. (2000b) found the highest concentrations of gray whales in summer off the Seward Peninsula, far to the south of the southern extent of GXT's proposed Chukchi Sea survey area. The distribution of gray whales in the proposed survey area was more scattered and limited to nearshore areas where most whales were observed in water less than 35 m deep (Moore et al. 2000b). Few whales ere expected in offshore waters so an arbitrary minimal density has been applied to the open water and ice margin areas (Table 3).

In the autumn, gray whales may be dispersed throughout the northern Chukchi Sea (in the area of the survey), and densities are expected to be somewhat higher. The Moore et al. (2000b) observed summer density was multiplied by 0.05 to estimate gray whale densities in open water (Table 4).

The remaining five cetacean species that could be encountered in the Chukchi Sea during GXT's proposed seismic survey include the narwhal, killer whale, minke whale, fin whale, and harbor porpoise. George and Suydam (1998) reported killer whales, Brueggeman et al. (1990) reported one minke whale, Suydam and George (1992) reported harbor porpoise near Pt. Barrow; and Gambell (1985) recorded the northern extent of fin whales to be in the Chukchi Sea. Although there is evidence of the occasional occurrence of these animals in the Chukchi Sea, it is unlikely that more than a few individuals would be encountered during the proposed survey and arbitrary minimal densities have been used (Tables 3 and 4). Only a few extralimital sightings of narwhals have been reported in the Chukchi Sea, so this species has not been addressed in this document.

TABLE 3. Expected densities of cetaceans and seals in areas of the **Chukchi Sea**, Alaska, for the planned **summer** seismic period. Densities are corrected for *f*(0) and *g*(0) biases. Species listed under the U.S. ESA as endangered are in italics.

Species	Open Water [a] Average Density (# / km2)	Open Water [a] Maximum Density (# / km2)	Ice Margin [b] Average Density (# / km2)	Ice Margin [b] Maximum Density (# / km2)
Odontocetes				
Monodontidae				
Beluga	0.0001	0.0004	0.0001	0.0004
Delphinidae				
Killer whale	0.0001	0.0004	0.0001	0.0004
Phocoenidae				
Harbor porpoise	0.0000	0.0000	0.0000	0.0000
Mysticetes				
Bowhead whale [c]	*0.0001*	*0.0003*	*0.0001*	*0.0003*
Gray whale	0.0000	0.0002	0.0000	0.0000
Minke whale	0.0001	0.0004	0.0001	0.0004
Fin whale	*0.0000*	*0.0001*	*0.0000*	*0.0001*
Pinnipeds				
Walrus [d]				
Bearded seal [e]	0.0093	0.0370	0.0925	0.3700
Spotted seal [f]	0.0002	0.0009	0.0001	0.0004
Ringed seal [e]	0.0234	0.0935	0.2338	0.9350
Carnivora				
Polar bear [d]				

[a] Open water regions for the Chukchi Sea are considered to be 85% of the seismic lines.
[b] Ice Margin regions for the Chukchi Sea are considered to be 15% of the seismic lines.
[c] Calculated from summer surveys in the Beaufort Sea summarized in Richardson and Thomson (eds., 2002).
[d] Walruses and polar bears are the subject of a separate IHA Application submitted by GXT to USFWS.
[e] Calculated from spring surveys of the Chukchi Sea coast by Bengtson et al. (2005).
[f] Calculated based on ratio of spotted seals to ringed seals reported by Moulton and Lawson (2002).

Pinnipeds

Four species of pinnipeds are likely to be encountered in the Chukchi Sea portion of GXT's proposed seismic survey: ringed seal, bearded seal, spotted seal, and walrus. Each of these species, except for the spotted seal, is most closely associated with the ice margin and the nearshore areas. The ice margin is considered preferred habitat (as compared to the nearshore areas) during most seasons, including spring, summer, and fall. Spotted seals are often considered to be predominantly coastal except in the spring when they may be found in the southern margin of the retreating sea ice, before they move to shore. However, satellite tagging has shown that they sometimes undertake long excursions at sea during summer (Lowry et al. 1994, 1998).

TABLE 4. Expected densities of cetaceans and seals in areas of the **Chukchi Sea**, Alaska, for the **fall** seismic period. Densities are corrected for *f*(0) and *g*(0) biases. Species listed under the U.S. ESA as endangered are in italics.

Species	Open Water [a] Average Density (# / km2)	Open Water [a] Maximum Density (# / km2)	Ice Margin [b] Average Density (# / km2)	Ice Margin [b] Maximum Density (# / km2)
Odontocetes				
Monodontidae				
Beluga [c]	0.0034	0.0135	0.0003	0.0014
Delphinidae				
Killer whale	0.0001	0.0004	0.0001	0.0004
Phocoenidae				
Harbor porpoise	0.0000	0.0000	0.0000	0.0000
Mysticetes				
Bowhead whale [d]	*0.0011*	*0.0060*	*0.0011*	*0.0060*
Gray whale [e]	0.0018	0.0072	0.0000	0.0000
Minke whale	0.0001	0.0004	0.0001	0.0004
Fin whale	0.0000	0.0001	0.0000	0.0001
Pinnipeds				
Walrus [f]				
Bearded seal [g]	0.0093	0.0370	0.0925	0.3700
Spotted seal [h]	0.0002	0.0009	0.0001	0.0004
Ringed seal [g]	0.0234	0.0935	0.2338	0.9350
Carnivora				
Polar bear [f]				

[a] Open water regions for the Chukchi Sea are considered to be 85% of the seismic lines.
[b] Ice Margin regions for the Chukchi Sea are considered to be 15% of the seismic lines.
[c] Adjusted from surveys by Moore et al. (2000b) in the Beaufort Sea.
[d] Calculated from summer surveys in the Beaufort Sea summarized in Richardson and Thomson (eds., 2002).
[e] Calculated from summer surveys by Moore et al. (2000b) in the Chukchi Sea.
[f] Walruses and polar bears are the subject of a separate IHA Application submitted by GXT to USFWS.
[g] Calculated from spring surveys of the Chukchi Sea coast by Bengtson et al. (2005).
[h] Calculated based on ratio of spotted seals to ringed seals reported by Moulton and Lawson (2002).

Densities for the three phocid species were derived from spring surveys of the eastern Chukchi Sea (Bengtson 2005). Seal densities for the Chukchi Sea survey area were assumed to be the same for both the summer (July) and autumn (October–November) periods.

Ringed seal and ***bearded seal*** densities in the Chukchi Sea ice margin were estimated to be 0.25× the average offshore pack ice densities reported by Bengtson (2005; zone 11P: 0.935 ringed seals/km^2 and 0.37 bearded seals/km^2; Tables 3 and 4). Both seal species are concentrated in the nearshore area in the spring when the Bengtson (2005) surveys were flown, so reported densities are not directly applicable to the timing and location of the planned survey. The open water density of ringed seals is expected to be 0.1× the ice margin estimate because open water areas surveyed by GXT will not have large numbers of ice pans.

The ***spotted seal*** density was based on the ratio of that species to ringed seals reported in Moulton and Lawson (2002). For spotted seals, Moulton and Lawson (2002) estimated a ratio of 0.01 spotted seals/ringed seals in the nearshore of the Alaskan Beaufort in summer. Spotted seals are known to occasionally forage in open water areas of the Chukchi (Frost and Lowry 1993) so the above ratio was used to estimate the open water density of spotted seals.

Walruses and ***polar bears*** are the subject of a separate IHA application submitted by GXT to USFWS (LGL 2006).

Potential Number of Cetacean "Exposures" to ≥160 and ≥170 dB

Average and Maximum Estimates of "Exposures" to ≥160 dB and ≥170 dB

The potential number of occasions when members of each species might be exposed to received levels ≥160 dB re 1 µPa (rms) (or ≥ 170 dB) was calculated by summing the results for each season and habitat zone by multiplying

- the expected species density, either "average" (i.e., best estimate) or "maximum", as described above (see Tables 3 and 4),
- the anticipated total line-kilometers of operations with the 36-airgun array in the time period, and habitat zone to which that density applies after applying a 25% allowance for possible additional line kilometers as noted earlier, and
- the cross-track distances within which received sound levels are predicted to be ≥160 or ≥170 dB (Table 2).

Some of the animals estimated to be exposed, particularly migrating bowhead whales, might show avoidance reactions before being exposed to ≥160 dB re 1 µPa (rms). Thus, these calculations actually estimate the number of exposures to ≥160 dB that would occur if there were no avoidance of the area ensonified to that level.

For the 36-airgun array, the cross track distance is 2× the predicted 160 dB radius predicted by the Gundalf model: 6000 m. Applying the approach described above, 55,560 km^2 of open-water habitat in the Chukchi Sea would be within the 160 dB isopleth over the course of the seismic project. After adding the aforementioned 25% contingency to the expected number of line kilometers, the number of exposures is calculated based on 69,450 km^2. The numbers of exposures in the two habitat categories (open water and ice margin) were then summed for each species.

The estimates show that one endangered cetacean species (the bowhead whale) is expected to be exposed to such noise levels unless bowheads avoid the approaching survey vessel before the received levels reach 160 dB. Migrating bowheads are likely to do so, though summering bowheads, if encountered, probably will not. For convenience, we refer to either eventuality as an "exposure". Our respective average and maximum estimates for bowhead whales are 59 and 337 (Table 7). One additional endangered cetacean species that theoretically might be encountered in the area is unlikely to be exposed. Fin whales occasionally occur near the area, but given their low "average" estimated densities in the area, few are likely to be exposed to ≥160 dB.

Most of the cetacean "exposures" to seismic sounds with received levels ≥160 dB would involve mysticetes (bowheads and gray whales) and monodontids (belugas). Average and maximum estimates of the number of exposures of cetaceans other than bowheads, in descending order, are beluga (163 and 650) and gray whale (84 and 337). The seasonal breakdown of these numbers is shown in Tables 5 and 6 and totaled in Table 7.

TABLE 5. Estimates of the numbers of marine mammals in areas where maximum received sound levels in the water would be ≥160 dB and ≥170 dB during **summer** (June and July) of GXT's proposed seismic program in the **Chukchi Sea**, Alaska, ~15 June – 25 July, 2006. The proposed sound source is a 36-airgun array (8×40 in^3, 4×70 in^3, 4×80 in^3, 12×100 in^3, 8×150 in^3) with a total discharge volume of 3320 in^3. Received levels of airgun sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration). Not all marine mammals will change their behavior when exposed to these sound levels, although some might alter their behavior somewhat when levels are lower (see text).

	Number of Exposure to Sound Levels >160 dB (>170 dB, Less Responsive Groups)					
	Summer					
	Open Water [a]		**Ice Margin [b]**		**Total**	
Species	**Average**	**Maximum**	**Average**	**Maximum**	**Average**	**Maximum**
Odontocetes						
Monodontidae						
Beluga	2	9	0	2	3	11
Delphinidae						
Killer whale	2 (0)	9 (2)	0 (0)	2 (0)	3 (0)	11 (2)
Phocoenidae						
Harbor porpoise	0	0	0	0	0	0
Mysticetes						
Bowhead whale	1	7	0	1	1	8
Gray whale	1	4	0	0	1	4
Minke whale	2	9	0	2	3	11
Fin whale	0	2	0	0	1	2
Total Cetaceans	10 (0)	40 (2)	2 (0)	6 (0)	11 (0)	47 (2)
Pinnipeds						
Bearded seal	212 (0)	848 (173)	374 (76)	1496 (305)	586 (76)	2344 (478)
Spotted seal	5 (0)	21 (4)	0 (0)	2 (0)	6 (0)	23 (4)
Ringed seal	536 (0)	2143 (437)	473 (96)	1891 (386)	1008 (96)	4033 (823)
Total Pinnipeds	753 (0)	3012 (614)	847 (173)	3388 (691)	1600 (173)	6401 (1305)

[a] Open water regions for the Chukchi Sea are considered to be 85% of the seismic lines outside of the nearshore portions.

[b] Ice Margin regions for the Chukchi Sea are considered to be 15% of the seismic lines outside of the nearshore portions.

TABLE 6. Estimates of the numbers of marine mammals in areas where maximum received sound levels in the water would be ≥160 dB and ≥170 dB during **fall** (October and November) of GXT's proposed seismic program in the **Chukchi Sea**, Alaska, ~1 October – 30 November, 2006. The proposed sound source is a 36-airgun array (8 × 40 in^3, 4 × 70 in^3, 4 × 80 in^3, 12 × 100 in^3, 8 × 150 in^3) with a total discharge volume of 3320 in^3. Received levels of airgun sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration). Not all marine mammals will change their behavior when exposed to these sound levels, although some might alter their behavior somewhat when levels are lower (see text).

	Number of Exposure to Sound Levels ≥160 dB (≥170 dB, Less Responsive Groups)					
	Fall					
	Open Water [a]		Ice Margin [b]		Total	
Species	**Average**	**Maximum**	**Average**	**Maximum**	**Average**	**Maximum**
Odontocetes						
Monodontidae						
Beluga	157	628	3	11	160	639
Delphinidae						
Killer whale	5 (1)	19 (4)	1 (0)	3 (1)	5 (1)	22 (4)
Phocoenidae						
Harbor porpoise	0	0	0	0	0	0
Mysticetes						
Bowhead whale	49	279	9	49	57	328
Gray whale	83	333	0	0	83	333
Minke whale	5	19	1	3	5	22
Fin whale	1	4	0	1	1	4
Total Cetaceans	299 (1)	1281 (4)	13 (0)	68 (1)	313 (1)	1349 (4)
Pinnipeds						
Bearded seal	430 (88)	1722 (351)	760 (155)	3038 (620)	1190 (243)	4760 (971)
Spotted seal	11 (2)	44 (9)	1 (0)	3 (1)	12 (2)	47 (10)
Ringed seal	1088 (222)	4351 (887)	960 (196)	3839 (783)	2047 (418)	8189 (1670)
Total Pinnipeds	1529 (312)	6116 (1247)	1720 (351)	6880 (1403)	3249 (663)	12996 (2651)

[a] Open water regions for the Chukchi Sea are considered to be 85% of the seismic lines outside of the nearshore portions.

[b] Ice Margin regions for the Chukchi Sea are considered to be 15% of the seismic lines outside of the nearshore portions.

TABLE 7. Summary of the number of potential exposures of marine mammals to received sound levels in the water of ≥160 dB and ≥170 dB during GXT's proposed seismic program in the Chukchi Sea, Alaska, ~15 June – 25 July and ~1 October – 30 November, 2006. Not all marine mammals will change their behavior when exposed to these sound levels, although some might alter their behavior somewhat when levels are lower (see text). The rightmost column of numbers (in boldface) shows the numbers of "harassment takes" for which authorization is requested.

	Number of Exposure to Sound Levels >160 dB (>170 dB, Less Responsive Groups)						
	Summer		**Fall**		**Total**		**Requested Take**
Species	**Average**	**Maximum**	**Average**	**Maximum**	**Average**	**Maximum**	**Authorization**
Odontocetes							
Monodontidae							
Beluga	3	11	160	639 0	163	650	**650**
Delphinidae							
Killer whale	3 (0)	11 (2)	5 (1)	22 (4)	8 (1)	33 (6)	**33**
Phocoenidae							
Harbor porpoise	0	0	0	0	0	0	**5**
Mysticetes							
Bowhead whale	1	8	57	328	59	337	**337**
Gray whale	1	4	83	333	84	337	**337**
Minke whale	3	11	5	22	8	33	**33**
Fin whale	1	2	1	4	2	7	**7**
Total Cetaceans	11 (0)	47 (2)	313 (1)	1349 (4)	324 (1)	1396 (6)	
Pinnipeds							
Bearded seal	586 (76)	2344 (478)	1190 (243)	4760 (971)	1776 (319)	7104 (1449)	**7104**
Spotted seal	6 (0)	23 (4)	12 (2)	47 (10)	17 (2)	70 (14)	**70**
Ringed seal	1008 (96)	4033 (823)	2047 (418)	8189 (1670)	3056 (514)	12223 (2493)	**12223**
Harbor seal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	**5**
Total Pinnipeds	1600 (173)	6401 (1305)	3249 (663)	12996 (2651)	4849 (835)	19397 (3956)	

The far right column in Table 7, "Requested Take Authorization", shows the numbers of animals for which "harassment take authorization" is requested. For the common species, the requested numbers are calculated as indicated above, based on the maximum densities calculated from the data reported in the different studies. In some cases, the requested numbers are somewhat higher than the maximum estimated numbers of exposures found in the second to last column of Table 7. Some of the marine mammal species that are known or suspected to occur at least occasionally in arctic waters were not recorded during the limited systematic surveys used to estimate densities. In those cases, the "Requested Take Authorization" figures include upward adjustments for small numbers that might be encountered.

Potential Number of Pinniped "Exposures" to ≥160 and ≥170 dB

Ringed Seals

The ringed seal is the most widespread and abundant pinniped in ice-covered arctic waters, and there is a great deal of annual variation in population size and distribution of these marine mammals. Ringed seals account for the vast majority of marine mammals expected to be encountered, and hence exposed to airgun sounds with received levels ≥160 dB re 1 µPa (rms) during the proposed seismic survey. Haley and Ireland (2006) reported that 20% of ringed seals remained on the ice when a seismic vessel passed. Because the sound level radii for this project are assumed to be larger than those in Haley and Ireland (2006), a larger percent of ringed seals within the radii are likely to remain on the ice while the ship passes. Therefore, our estimates of numbers of ringed seals that might be exposed to sound levels ≥160 dB and ≥170 dB re 1 µPa (rms) were reduced by 50% to account for animals that are expected to be out of the water, and hence exposed to much lower levels of seismic sounds. The average (and maximum) estimate is that 3056 (12,223) ringed seals might be exposed to seismic sounds with received levels ≥160 dB, accounting for 59% of the cetaceans and seals that might be so exposed. This exposure estimate assumes as many as 50% of ringed seals encountered in the ice margin will actually be hauled out on ice where they would not be exposed to water-borne seismic sounds.

Pinnipeds are not likely to react to seismic sounds unless the received levels are ≥170 dB re 1 µPa (rms), and many of those exposed to 170 dB also will not react overtly (Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). In any event, the best and maximum estimates of numbers of ringed seals that might be exposed to sounds ≥170 dB are 514 and 2493, respectively, if 50% of seals encountered in the ice margin were in or entered the water.

Other Pinniped Species

Three other species of pinnipeds are expected to be encountered during the proposed seismic survey; one other species (harbor seal) is unlikely to be encountered, but its presence cannot be ruled out (Table 7). The walrus is under the jurisdication of the USFWS and is the subject of a separate IHA application submitted to that agency on 9 March 2006 (LGL 2006). The remaining two species expected to be encountered are the bearded seal (1776 and 7104, average and maximum estimates, respectively), and spotted seal (17 and 70; Table 7). Since pinnipeds are not likely to react to seismic sounds unless the received levels are ≥170 dB re 1 µPa (rms), the more relevant numbers for bearded seals are 319 and 1449, and for spotted seals they are 2 and 14. As mentioned above for ringed seals, many of these animals will be hauled out on ice, and therefore would not be exposed to the strong seismic sounds to which they would be exposed if they were in the water. However, no specific estimate of the proportion of individuals of these species that can be expected to remain out of the water was available, so no correction was made.

Conclusions

The proposed survey in the Chukchi Sea will involve towing a 36-airgun array that will introduce pulsed sounds into the ocean, along with simultaneous operation of a pinger system. Routine vessel operations, other than the proposed operations by the airguns, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". For similar reasons, no "taking" is expected from the use of the pinger system given the considerations discussed in § I and § VII(b,c), i.e., relatively high operating frequency, short pulse duration, and low duty cycle, and brief (if any) behavioral response.

Potential Bowhead Disturbance at Lower Received Levels

During autumn seismic surveys in the Beaufort Sea, migrating bowhead whales displayed avoidance at distances out to 20–30 km and received sound levels of ~130 dB (rms) (Miller et al. 1999; Richardson et al. 1999). Therefore, it is possible that a larger number of bowhead whales than estimated above may be disturbed to some extent if reactions occur at ≥130 dB (rms). However, GXT is not planning seismic activities in the U.S. Beaufort Sea during the fall bowhead hunting period and most bowhead whales will likely be west of the Chukchi Sea survey area when the seismic survey resumes there in the fall. (In autumn, most bowheads travel to Russian waters north of the Chukotsk Peninsula.) Enounters with bowhead whales in the fall would occur after the hunting season and in the Chukchi Sea where the bowhead whale migration corridor becomes bifurcated and much broader than where the Miller et al. (1999) study took place. Whether bowhead whales display avoidance at received sound levels ~130dB (rms) during fall in the Chukchi Sea is not known.

Cetaceans

Strong avoidance reactions by several species of mysticetes to seismic vessels operating large arrays of airguns have been observed at ranges up to 6–8 km and occasionally as far as 20–30 km from the source vessel. However, reactions at the longer distances appear to be atypical of most species and situations, particularly when feeding whales are involved (Miller et al. 2005). Odontocete reactions to seismic pulses are usually assumed to be limited to lesser distances from the airgun(s) than are those of mysticetes, probably in part because odontocete low-frequency hearing is less sensitive than that of mysticetes. However, at least when in the Canadian Beaufort Sea in summer, belugas appear to be fairly responsive to seismic surveys, with few being sighted within 10–20 km during aerial surveys (Miller et al. 2005).

Taking into account the mitigation measures that are planned, effects on cetaceans are generally expected to be restricted to avoidance of a limited area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment". Furthermore, the estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are relatively low percentages of the population sizes in the Bearing–Chukchi–Beafort seas, as described below.

Based on the 160 dB criterion, the *best (average) estimates* of the numbers of cetacean *exposures* to sounds ≥160 dB re 1 μPa (rms) represent varying proportions of the populations of each species in the Chukchi Sea and adjacent waters (*cf.* Table 2). For species listed as "Endangered" under the ESA, our estimates include ~2 fin whales and ~59 bowheads. The latter is <1% of the Bering-Chukchi-Beaufort population of >10,545+ (*cf.* Table 2).

Some monodontids may be exposed to sounds produced by the airgun arrays during the proposed seismic study, and the numbers potentially affected are small relative to the population sizes (Table 7).

Narwhals are extremely rare in the Chukchi Sea and none are expected to be encountered during the survey. The best estimate of the number of belugas that might be exposed to ≥160 dB is 163) represents <1% of their population.

Varying estimates of the numbers of marine mammals that might be exposed to sounds from the airgun array during the 2006 GXT seismic survey have been presented, depending on the specific exposure criteria (≥160 vs. ≥170 dB) and density criteria used (average vs. maximum). The requested "take authorization" for each species is based on the estimated *maximum number of exposures* to ≥160 dB re 1 μPa (rms), i.e., the highest of the various estimates. The relatively short-term exposures that will occur are not expected to result in any long-term negative consequences for the individuals or their populations.

The many reported cases of apparent tolerance by cetaceans of seismic exploration, vessel traffic, and some other human activities show that co-existence is possible. Mitigation measures such as controlled speed, look outs, non-pursuit, shut downs or power downs when marine mammals are seen within defined ranges, and avoiding migration pathways when animals are likely most sensitive to noise will further reduce short-term reactions, and minimize any effects on hearing sensitivity. In all cases, the effects are expected to be short-term, with no lasting biological consequence. Subsistence issues are addressed below in § VIII.

Pinnipeds

A few pinniped species are likely to be encountered in the study area, but the ringed seal is by far the most abundant marine mammal that will be encountered. The *best (average) estimates* of the numbers of *exposures* to airgun sounds at received levels ≥160 dB re 1 μPa (rms) during the seismic survey are as follows: ringed seals (3056), bearded seals (1776), and spotted seals (17), (representing <2%, <1%, and <2%, respectively, of their Bearing–Chukchi–Beaufort populations). It is probable that only a small percentage of those would actually be disturbed.

As for cetaceans, the short-term exposures of pinnipeds to airgun sounds are not expected to result in any long-term negative consequences for the individuals or their populations.

Walruses and polar bears are the subject of a separate IHA application submitted by GXT to USFWS (LGL 2006).

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

Subsistence hunting and fishing continue to be prominent in the household economies and social welfare of some Alaskan residents, particularly among those living in small, rural villages (Wolfe and Walker 1987). Subsistence remains the basis for Alaska Native culture and community. In rural Alaska, subsistence activities are often central to many aspects of human existence, including patterns of family life, artistic expression, and community religious and celebratory activities.

Subsistence hunting

Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives; species hunted include bowhead and beluga whales; ringed, spotted, and bearded seals; walruses, and polar bears. The importance of each of the various species varies among the communites based largely on availability. Bowhead whales, belugas, and walruses are the marine mammal species primarily harvested during the time of the proposed seismic survey. There is little or no bowhead hunting by the community of Point Lay, so beluga and walrus hunting are of more importance there. Members of the Wainwright community hunt bowhead whales in the spring, although bowhead whale hunting conditions there are often more difficult than elsewhere, and they do not hunt bowheads during seasons when GXT's seismic operation would occur. Depending on the level of success during the spring bowhead hunt, Wainwright residents may be very dependent on the presense of belugas in a nearby lagoon system during July and August. Barrow residents focus hunting efforts on bowhead whales during the spring and generally do not hunt beluga then (Table 8). However, Barrow residents also hunt in the fall, when GXT expects to be conducting seismic surveys (though not near Barrow).

Bowhead whale hunting is a key activity in the subsistence economies of Barrow and Wainwright. The whale harvests have a great influence on social relations by strengthening the sense of Inupiat culture and heritage in addition to reinforcing family and community ties.

An overall quota system for the hunting of bowhead whales was established by the International Whaling Commission in 1977. The quota is now regulated through an agreement between NMFS and the Alaska Eskimo Whaling Commission (AEWC). The AEWC allots the number of bowhead whales that each whaling community may harvest annually (USDI/BLM 2005).

Bowhead whales migrate around northern Alaska twice each year, during the spring and autumn, and are hunted in both seasons. Bowhead whales are hunted from Wainwright only during the spring migration and animals are not successfully harvested every year (Table 8). The spring hunt there and at Barrow occurs after leads open due to the deterioration of pack ice; the spring hunt typically occurs from early April until the first week of June. The fall migration of bowhead whales that summer in the eastern Beaufort Sea typically begins in late August or September. Fall migration into Alaskan waters is primarily during September and October. However, in recent years a small number of bowheads have been seen or heard offshore from the Prudhoe Bay region during the last week of August (Treacy 1993; LGL and Greeneridge 1996; Greene 1997; Greene et al. 1999; Blackwell et al. 2004).

The location of the fall subsistence hunt near Barrow depends on ice conditions and (in some years) industrial activities that influence the bowheads movements as they move west (Brower 1996). In the fall, subsistence hunters use aluminum or fiberglass boats with outboards. Hunters prefer to take bowheads close to shore to avoid a long tow during which the meat can spoil, but Braund and Moorehead (1995) report that crews may (rarely) pursue whales as far as 80 km. The autumn bowhead hunt usually begins in Barrow in mid-September, and mainly occurs in the waters east and northeast of Point Barrow. The whales have usually left the Beaufort Sea by late October (Treacy 2002a,b).

The scheduling of this seismic survey has been discussed with representatives of those concerned with the subsistence bowhead hunt, most notably the AEWC, the Barrow Whaling Captains' Association, and the North Slope Borough (NSB) Department of Wildlife Management.

The planned starting date for seismic surveys in the Chukchi Sea (~15 June) is well after the end of the spring bowhead migration and hunt at Wainwright and Barrow. Similarly, the resumption of seismic activities in the Chukchi Sea in October will occur after most subsistence whaling from Barrow has been completed and if the hunt is still active, seismic operations will be conducted far from Barrow to avoid conflicting with subsistence hunting activities.

TABLE 8. Bowhead landings at Wainwright and Barrow 1993–2004.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Wainwright [a]	5	4	5	3	3	3	5	5	6	?	?	4
Barrow [b]	23(7)	16(1)	20(11)	24(19)	31(21)	25(16)	24(6)	18(13)	26(7)	20(17)	16(6)	21(14)

[a] Complied in USDI/BLM (2003) from various sources. Wainwright landings are in spring. 2002 and 2003 data were missing.

[b] Numbers given for Barrow are "total landings/autumn landings". From Burns et al. (1993), various issues of *Report of the International Whaling Commission*, Alaska Eskimo Whaling Commission, J.C. George (NSB Dep. Wildl. Manage.).

Beluga whales are available to subsistence hunters along the coast of Alaska in the spring when pack-ice conditions deteriorate and leads open up. Belugas may remain in coastal areas or lagoons through June and sometimes into July and August. The community of Point Lay is heavily dependent on the hunting of belugas in Kasegaluk Lagoon for subsistence meat. From 1983–1992 the average annual harvest was ~40 whales (Fuller and George 1997). In Wainwright and Barrow, hunters usually wait until after the spring bowhead whale hunt is finished before turning their attention to hunting belugas. The average annual harvest of beluga whales taken by Barrow for 1962–1982 was five (MMS 1996). The Alaska Beluga Whale Committee recorded that 23 beluga whales had been harvested by Barrow hunters from 1987 to 2002, ranging from 0 in 1987, 1988 and 1995 to the high of 8 in 1997 (Fuller and George 1997; Alaska Beluga Whale Committee 2002 *in* USDI/BLM 2005; Table 9). It is possible, but unlikely, that accessibility to belugas during the subsistence hunt could be impaired during the survey. GXT does not plan to survey within 25 km of the Chukchi coast and survey activities will not be conducted within the polynya zone defined in § II. That means the vessel will be well offshore away from areas where seismic surveys would influence beluga hunting by these communities.

Ringed seals are hunted mainly from October through June. Hunting for these smaller mammals is concentrated during winter because bowhead whales, bearded seals and caribou are available through other seasons. In winter, leads and cracks in the ice off points of land and along the barrier islands are used for hunting ringed seals. The average annual ringed seal harvests by the various communities are presented in Table 9. Although ringed seals are available year-round, the seismic survey will not occur during the primary period when these seals are typically harvested. Also, the seismic survey will be largely in offshore waters where the activities will not influence ringed seals in the nearshore areas where they are hunted.

The ***spotted seal*** subsistence hunt peaks in July and August along the shore where the seals haul out, but usually involves relatively few animals (Table 9). Spotted seals typically migrate south by October to overwinter in the Bering Sea. During the fall migration spotted seals are hunted by the Wainright and Point Lay communities as the seals move south along the coast (USDI/BLM 2003). Spotted seals are also occasionally hunted in the area off Point Barrow and along the barrier islands of Elson Lagoon to the east (USDI/BLM 2005). The seismic survey will remain offshore of the coastal harvest area of these seals and should not conflict with harvest activities.

Bearded seals, although generally not favored for their meat, are important to subsistence activities in Barrow and Wainright, because of their skins. Six to nine bearded seal hides are used by whalers to cover each of the skin-covered boats traditionally used for spring whaling. Because of their valuable hides and large size, bearded seals are specifically sought. Bearded seals are harvested during the spring and summer months in the Chukchi Sea (USDI/BLM 2003, 2005; Table 9). The animals inhabit the environment around the ice floes in the drifting nearshore ice pack, so hunting usually occurs from boats

TABLE 9. Average[a] annual take of marine mammals other than bowhead whales harvested by the communities of Point Lay, Wainwright, and Barrow.

	Walruses	Beluga Whales	Ringed Seals	Bearded Seals	Spotted Seals
Point Lay	3	31	49	13	53
Wainwright	58	8	86	74	12
Barrow	46	2	394	175	4

[a] Includes one or more harvests from 1987-1999 (Braund et al. 1993; USDI/BLM 2003, 2005)

in the drift ice. Most bearded seals are harvested in coastal areas inshore of the proposed survey so no conflicts with the harvest of bearded seals are expected. Issues relating to ***polar bears*** and **walruses** are being addressed by ongoing coordination between GXT and USFWS. However, for completeness, concerns about interactions with subsistence hunting of these two species are summarized briefly here.

The USFWS has monitored the harvest of polar bears in Alaska using a mandatory marking, tagging, and reporting program implemented in 1988. Polar bears are harvested in the winter and spring, but comprise a small percent of the annual subsistence harvest. The USFWS estimated that, from 1995 to 2000, the average annual harvest of the Southern Beaufort Sea polar bear stock in Alaska was 32 (Angliss and Lodge 2004). That includes harvests at all coastal communities. It is not expected that the seismic survey will interfere with polar bear subsistence hunting due to the limited annual harvest documented by USFWS and the fact that the subsistence hunt typically takes place in the winter and spring, either well after or well before the scheduled survey.

Walruses are hunted primarily from June through mid-August in Chukchi waters to the west of Point Barrow and southwest to Peard Bay. The harvest effort peaks in July–August and is often conducted at the same time as the hunting of bearded seals. The annual walrus harvest by Barrow residents ranged from 7 to 206 animals from 1990 to 2002, and ranged from 0 to 4, and 0 to 153 for the Point Lay and Wainwright communities, respectively (Fuller and George 1997; Schliebe 2002 *in* USDI/BLM 2005; USDI/BLM 2003). It is possible, but unlikely, that accessibility to walruses during the subsistence hunt could be impaired during seismic surveys in the Chukchi Sea. However, the seismic survey will not be conducted within the polynya zone where marine mammal migrate during the spring, designated by the southeastern border of the MMS lease sale area 193.

In the event that both marine mammals and hunters were near the *Discoverer* when seismic surveys are in progress, the proposed project potentially could impact the availability of marine mammals for harvest in a small area immediately around the vessel, in the case of pinnipeds, and possibly in a large area in the case of migrating bowheads. However, the majority of marine mammals are taken by hunters within ~33 km of shore (Fig. 4), and the *Discoverer* will remain outside the polynya zone (~25 km from shore). Considering the timing and location of the proposed seismic survey activities, as described in § I and II, the proposed project is not expected to have any significant impacts to the availability of marine mammals for subsistence harvest. Specific concerns of the respective communities will be addressed as part of the Plan of Cooperatin / Conflict Avoidance Agreement that is being negotiated with the AEWC (see § XII, below).

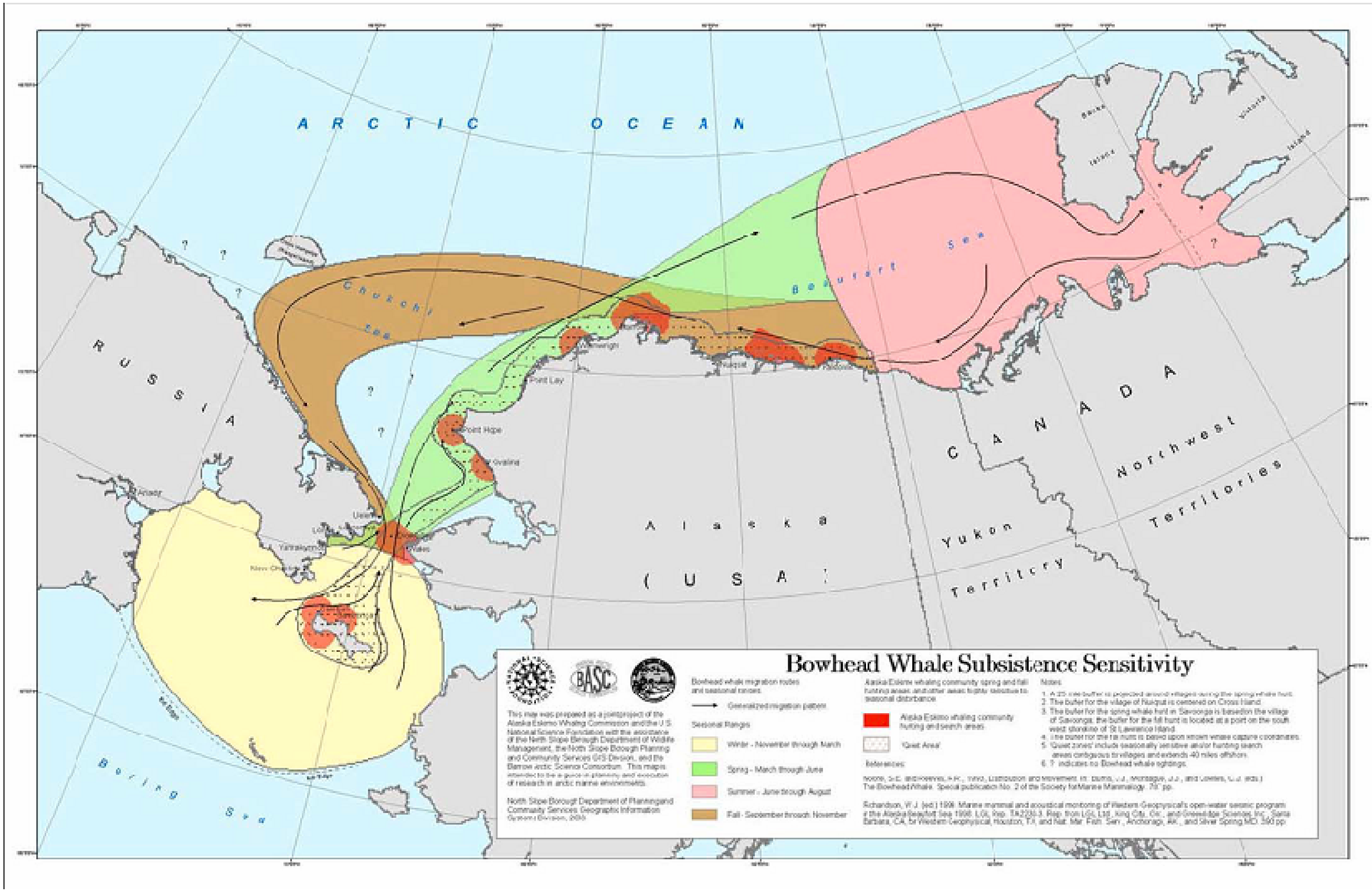

FIGURE 4. Bowhead subsistence harvest areas indicating the extent offshore where subsistence hunting is conducted (NSF 2004).

Subsistence Fishing

Subsistence fishing is conducted through the year, but most actively during the summer and fall months. Fishing is often done as a source of food in the hunting camps, so the geographic range of subsistence fishing is widespread. Marine subsistence fishing occurs during the harvest of other subsistence resources in the summer. Most fishing occurs in coastal areas and thus well away from the offshore waters where a majority of the survey will be conducted (MMS 1996).

Seismic surveys can, at times, cause changes in the catchability of fish. In the unlikely event that subsistence fishing (or hunting) is occurring within 5 km (3 mi) of the *Discoverer's* trackline, or within other situations inconsistent with the Conflict Avoidance Agreement, the airgun operations will be suspended until the *vessel* is >5 km away and otherwise in compliance with the CAA.

IX. ANTICIPATED IMPACT ON HABITAT

The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

The proposed seismic survey will not result in any permanent impact on habitats used by marine mammals, or to the food sources they utilize. The proposed activities will be of short duration in any particular area at any given time; thus any effects would be localized and short-term. However, the main impact issue associated with the proposed activity will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VI/VII, above.

One of the reasons for the adoption of airguns as the standard energy source for marine seismic surveys was that, unlike explosives, they do not result in any appreciable fish kill. However, the existing body of information relating to the impacts of seismic on marine fish and invertebrate species, the primary food sources of pinnipeds and belugas, is very limited.

In water, acute injury and death of organisms exposed to seismic energy depends primarily on two features of the sound source: (1) the received peak pressure, and (2) the time required for the pressure to rise and decay (Hubbs and Rechnitzer 1952; Wardle et al. 2001). Generally, the higher the received pressure and the less time it takes for the pressure to rise and decay, the greater the chance of acute pathological effects. Considering the peak pressure and rise/decay time characteristics of seismic airgun arrays used today, the pathological zone for fish and invertebrates would be expected to be within a few meters of the seismic source (Buchanan et al. 2004). For the proposed survey, any injurious effects on fish would be limited to very short distances, and thus to areas well away from the nearshore waters where most subsistence fishing activities occur.

The only designated Essential Fish Habitiat (EFH) species that may occur in the area of the project during the seismic survey are salmon (adult), and their occurrence in waters north of the Alaska coast is limited. Adult fish near seismic operations are likely to avoid the immediate vicinity of the source, thereby avoiding injury. No EFH species will be present as very early life stages when they would be unable to avoid seismic exposure that could otherwise result in minimal mortality.

The proposed Chukchi Sea seismic program for 2006 is predicted to have negligible to low physical effects on the various life stages of fish and invertebrates. Therefore, physical effects of the proposed program on the fish and invertebrates would not be significant

X. ANTICIPATED IMPACT OF LOSS OR MODIFICATION OF HABITAT ON MARINE MAMMALS

The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.

The proposed airgun operations will not result in any permanent impact on habitats used by marine mammals, or to the food sources they use. The main impact issue associated with the proposed activities will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed above.

During the seismic study only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species would be short-term and fish would return to their pre-disturbance behavior once the seismic activity ceases. Thus, the proposed survey would have little, if any, impact on the abilities of marine mammals to feed in the area where seismic work is planned.

Some mysticetes, including bowhead whales, feed on concentrations of zooplankton. Some feeding bowhead whales may occur in the Alaskan Beaufort Sea in July and August, and others feed intermittently during their westward migration in September and October (Richardson and Thomson [eds.] 2002; Lowry et al. 2004). However, by the time most bowhead whales reach the Chukchi Sea (October), they will likely no longer be feeding. A reaction by zooplankton to a seismic impulse would only be relevant to whales if it caused concentrations of zooplankton to scatter. Pressure changes of sufficient magnitude to cause that type of reaction would probably occur only very close to the source. Impacts on zooplankton behavior are predicted to be negligible, and that would translate into negligible impacts on feeding mysticetes.

Thus, the proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, since operations at any specific location will be limited in duration.

XI. MITIGATION MEASURES

The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.

For the proposed seismic survey in the Chukchi and Beaufort seas, GXT will deploy and airgun source composed of 36 sleeve airguns. The airguns comprising the array will be spread out horizontally, so that most the energy will be directed downward. The directional nature of the array to be used in this project is an important mitigating factor. This directionality will result in reduced sound levels at any given horizontal distance compared to levels expected at that distance if the source were omnidirectional with the stated nominal source.

Important mitigation factors built into the design of the survey include the fact that the spring migration and hunt for bowhead whales in Chukchi waters will be completed prior to the start of the survey. Also, it is likely that many bowhead whales will have already reached Russian waters north of the Chukotsk Peninsula when surveying is expected to resume in the autumn. Thus, the density of bowhead whales encountered during the fall in the Chukchi Sea, where the migration corridor becomes bifurcated and broad, is expected to be much lower than that of the Beaufort Sea during the fall, where the migration corridor is narrow (Richardson and Thomson 2002).

Received sound fields were modeled by GXT for the 36-airgun configuration, in relation to distance and direction from the array. The distance from the array by which received levels would have diminished to 190, 180, 160 and other levels (in dB re 1 μPa rms) are likely to depend on water depth and location. Table 2 presents the predicted sound radii for the 36-airgun array in intermediate (200–500 m) water depths. The radii for deeper or shallower water are predicted by GXT to be smaller than those for intermediate depths.

Empirical data concerning these radii are not yet available, but will be acquired early in the 2006 field season. In addition to performing an acoustic characterization/verification of the full 36-airgun array at different depths, the output from a single 40 in^3 sleeve airgun source will also be measured in order to determine the appropriate safety radius for use during power downs. A summary report on the acoustic measurements and proposed refinements to the safety radii will be made available for review shortly after the data have been collected. Until these empirical data are available, the radii predicted to be applicable to intermediate water depths (with a precautionary 1.5× adjustment) will also be applied for deep and shallow water operations when estimating the required safety radii. More detailed modeling of the airgun array may be completed prior to the beginning of the field season and the resulting 180 and 190 dB (rms) safety radii (with ×1.5 factor) will be applied at the start of the season if that occurs.

Vessel-based observers will watch for marine mammals near the airgun(s) when they are in use during daytime and during nighttime start ups. Mitigation and monitoring measures proposed to be implemented for the proposed seismic survey have been developed and refined in cooperation with NMFS during previous seismic studies and associated EAs, IHA Applications, and IHAs. The mitigation and monitoring measures described herein represent a combination of the procedures required by past IHAs. The measures are described in detail below.

The number of individual animals expected to be closely approached during the proposed activity will be small in relation to regional population sizes. With the proposed monitoring, ramp-up, power-down, and shut-down provisions (see below), any effects on individuals are expected to be limited to behavioral disturbance. That is expected to have negligible impacts on the species and stocks.

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity.

Marine Mammal Monitoring

Vessel-based observers will monitor marine mammals near the seismic source vessel during all daytime airgun operations and during any nighttime start ups of the airguns. These observations will provide the real-time data needed to implement some of the key mitigation measures. When marine mammals are observed within, or about to enter, designated safety zones (see below) where there is a possibility of significant effects on hearing or other physical effects, airgun operations will be powered down (or shut down if necessary) immediately.

- During daylight, vessel-based observers will watch for marine mammals near the seismic vessel during all periods with shooting and for a minimum of 30 min prior to the planned start of airgun operations after an extended shut down.

- GXT proposes to conduct nighttime as well as daytime operations. Observers dedicated to marine mammal observations are proposed not to be on duty during ongoing seismic operations at night, given the very limited effectiveness of visual observation at night. At night, bridge personnel will watch for marine mammals (insofar as practical at night) and will call for the airguns to be shut down if marine mammals are observed in or about to enter the safety radii. If the airguns need to be started up at night, two marine mammal observers (MMOs) will monitor marine mammals near the source vessel for 30 min prior to start up of the airguns using night vision devices (NVD), if the proper conditions for nighttime start up exist (see later).

Proposed Safety Radii

Received sound levels were modeled by GXT for the different airgun configurations, in relation to distance and direction from the 36-airguns (Fig. 2, 3). The model is most directly applicable to intermediate water depths (200–500 m). Based on the model, Table 2 shows the distances from the airguns where GXT predicts that sound levels of 190, 180, 170, and 160 dB re 1 µPa (rms) will be received.

Empirical data concerning the 180, 170 and 160 dB distances have not been acquired for the 36-airgun array to be used here. However, empirical data for other airgun configurations have showed that water depth often affects the radii around the airguns where received level would be 180 dB re 1 µPa (rms), the safety criterion applicable to cetaceans (NMFS 2000). Some depth-related variation is also likely in the 190 dB distances applicable to pinnipeds. As described above, the plan is to measure received sound levels as a function of distance from the array (if possible during operations in different water depths) early in the course of the study. GXT will then apply appropriate adjustments to the safety radii based on those data. In the absence of specific data from other water depths, the radii for intermediate depths will be applied to both deep (>500 m) and shallow (<200 m) water operations when estimating the area ensonified and numbers of animals disturbed. More detailed modeling of sounds produced by the planned airgun array may be completed prior to the field season. Results of any such modeling will be made available before the field season, and the predicted safety radii for various water depths will be used in lieu of the current estimates (Table 2).

Airguns will be powered down (or shut down if necessary) immediately when marine mammals are detected within or about to enter the applicable ≥180 or ≥190-dB (rms) radius. These planned power-down and shut down criteria are consistent with guidelines listed for cetaceans and pinnipeds by NMFS (2000), and other guidance by NMFS. Little information is available about the effects of noise on polar bears, and we propose to apply the 190 dB (rms) radius as the “safety criterion” for them when they have their heads underwater.

Mitigation During Operations

In addition to monitoring, mitigation measures that will be adopted will include (1) speed or course alteration, provided that doing so will not compromise operational safety requirements, (2) power down or shut-down procedures, and (3) no start up of airgun operations unless the full 190 dB safety zone is visible for at least 30 min during day or night. **Note that point (3) differs from recent practice in some other projects,** in that it is here proposed that the 190 dB radius, but not necessarily the full 180 dB radius, must be visible before a ramp up can commence. The rationale for this is as follows:

- Pinnipeds, to which the 190 dB safety zone applies, have not shown much avoidance of operating seismic arrays (Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). Therefore, it is appropriate to assume that some pinnipeds might not move out of the safety zone during a ramp up. Accordingly, the 190 dB zone should be visible before a ramp-up begins.

- The types of cetaceans likely to be encountered (bowheads and belugas) have shown avoidance of active seismic surveys and it is expected that they will move beyond the full 180 dB radius for the 36-gun array during the ramp up. Thus, it is not critical that the full 180 dB radius applicable to cetaceans be visible prior to commencing a ramp up.

Other proposed provisions associated with operations at night or in periods of poor visibility include the following:

- During foggy conditions or darkness (which may be encountered starting in late August), the full 190 dB (rms) safety radius may not be visible, especially during operations in intermediate or shallow water depths. In that case, the airguns could not start up from a full shut down.

- During any nighttime operations, if the entire 190 dB safety radius is visible using vessel lights and/or NVDs[1], then start up of the airgun array may occur following a 30-min period of observation without sighting marine mammals in the safety radius.

- If one or more airguns have been operational before nightfall, they can remain operational throughout the night, even though the entire safety radius may not be visible.

The mitigation and marine mammal monitoring measures listed and described below will be adopted during the proposed seismic program, provided that doing so will not compromise operational safety requirements:

1. Speed or course alteration;
2. Power-down procedures;
3. Shut-down procedures; and

Speed or Course Alteration

If a marine mammal (in water) is detected outside the safety radius and, based on its position and the relative motion, is likely to enter the safety radius, the vessel's speed and/or direct course may, when practical and safe, be changed in a manner that also minimizes the effect on the planned science objectives. The marine mammal activities and movements relative to the seismic vessel will be closely monitored to ensure that the marine mammal does not approach within the safety radius. If the mammal appears likely to enter the safety radius, further mitigative actions will be taken, i.e., either further course alterations or power down or shut down of the airgun(s).

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radii of the 190-dB and 180-dB zones are decreased to the extent that observed marine mammals are not in the applicable safety zone. A power down may also occur when the vessel is moving from one seismic line to another. During a power down, one airgun (or some other number of airguns less than the full airgun array) is

[1] See Smultea and Holst (2003), Holst (2004), Smultea et al. (2004), and Stoltz and MacLean *in* MacLean and Koski (2005) for an evaluation of the effectiveness of night vision equipment for nighttime marine mammal observations.

operated. The continued operation of one airgun is intended to (a) alert marine mammals to the presence of the seismic vessel in the area, and (b) retain the option of initiating a ramp up to full operations under poor visibility conditions. In contrast, a shut down occurs when all airgun activity is suspended.

If a marine mammal is detected outside the safety radius but is likely to enter the safety radius, and if the vessel's speed and/or course cannot be changed to avoid having the mammal enter the safety radius, the airguns may (as an alternative to a complete shut down) be powered down before the mammal is within the safety radius. Likewise, if a mammal is already within the safety zone when first detected, the airguns will be powered down immediately if this is a reasonable alternative to a complete shut down. During a power down of the 36-airguns, the number of guns operating will be reduced to a single 40 in^3 sleeve airgun. The 190 dB (rms) safety radius around the power down source has not yet been estimated, but will be estimated before the field season and verified during acoustic verification measurements made at the start of seismic operations. If a marine mammal is detected within or near the smaller safety radius around the single 40 in^3 sleeve airgun, all airguns will be shut down (see next subsection).

Following a power down, operation of the full airgun array will not resume until the marine mammal has cleared the safety zone. The animal will be considered to have cleared the safety zone if it

- is visually observed to have left the safety zone, or
- has not been seen within the zone for 15 min in the case of small odontocetes and pinnipeds, or
- has not been seen within the zone for 30 min in the case of mysticetes (large odontocetes do not occur within the study area).

Shut-down Procedures

The operating airgun(s) will be shut down completely if a marine mammal approaches or enters the then-applicable safety radius and a power down is not practical or adequate to reduce exposure to less than 190 or 180 dB (rms), as appropriate. The operating airgun(s) will also be shut down completely if a marine mammal approaches or enters the estimated safety radius around the reduced source (one 40 in^3 airgun) that will be used during a power down.

Airgun activity will not resume until the marine mammal has cleared the safety radius. The animal will be considered to have cleared the safety radius as described above. Ramp-up procedures will be followed during resumption of full seismic operations.

Ramp-up Procedures

A “ramp up” procedure will be followed when the airgun array begins operating after a specified-duration period with no or reduced airgun operations. The specified period depends on the speed of the source vessel, the size of the airgun array that is being used, and the size of the safety radii, but is often about 10 min.

NMFS normally requires that, once ramp up commences, the rate of ramp up be no more than 6 dB per 5 min period. Ramp up will likely begin with a single airgun (the smallest, or 40 in^3). The precise ramp-up procedure has yet to be determined, but GXT intends to follow NMFS’ guideline (or whatever guideline USFWS adopts) with a ramp up rate of no more than 6 dB per 5 min period. A common procedure is to double the number of operating airguns at 5-min intervals. During the ramp-up, the safety zone for the full 36-airgun array (or whatever smaller source might then be in use) will be maintained.

If the complete 190 dB safety radius has not been visible for at least 30 min prior to the planned start of a ramp-up in either daylight or nighttime, ramp up will not commence unless at least one airgun has been operating during that period. This means that it will not be permissible to ramp up the 36-airguns from a complete shut down in thick fog when the entire 190 dB safety zone is not visible. If the entire safety radius is visible using vessel lights and/or NVDs, then start up of the airguns from a complete shut down may occur at night. If one airgun has operated during a power-down period, ramp up to full power will be permissible at night or in poor visibility, on the assumption that marine mammals will either be alerted by the sounds from the single airgun and could move away, or may be detected by visual observations. Given the responsiveness of bowhead and beluga whales to airgun sounds, it can be assumed that those species, in particular, will move away during a ramp up. There have been direct observations of bowheads moving away when a single airgun begins to operate (Richardson et al. 1986; Ljungblad et al. 1988).

Ramp up of the airguns will not be initiated during the day or at night if a marine mammal has been sighted within or near the applicable safety radius during the previous 15 min.

XII. PLAN OF COOPERATION

Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:

(i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;
(ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;
(iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and
(iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

GXT has begun negotiating a "Plan of Cooperation" for the proposed 2006 seismic survey in the Chukchi Sea, in consultation with representatives of communities along the Alaska coast including Pt. Hope, Pt. Lay, Wainwright, Barrow. GXT is working with the people of these communities to identify and avoid areas of potential conflict, including a presentation at the AEWC mini-convention in Anchorage, Alaska, on 15 March 2006. Meetings with AEWC and NSB representatives also occurred at the time of the convention, and further communication is ongoing leading toward adoption of a Plan of Cooperation / Conflict Avoidance Agreement. Also, GXT plans to participate in the "open water peer/stakeholder review meeting" to be convened by NMFS in Anchorage in mid-April 2006, where representatives of the AEWC and NSB are also expected to participate.

At least one Alaska Native knowledgeable about the mammals and fish of the area is expected to be included as a member of the MMO team aboard the *Discoverer*. The primary duty of this individual will be as a member of the MMO team responsible for implementing the monitoring and mitigation requirements. However, the Alaska Native MMO will also be the "Inupiat Communicator" who is expected to be required under provisions of the Conflict Avoidance Agreement. The Communicator will provide for liaison with hunters and fishers if they are encountered at sea, and with the Whaler Communication Center that is expected to be established. However, the proposed activity is not expected to encounter subsistence hunters at sea, and is not expected to affect the success of subsistence hunters or fishers.

The Plan of Cooperation will cover the phases of GXT's seismic survey planned to occur in the Beaufort and Chukchi seas between 15 June and 30 November. The purpose of this plan will be to identify measures that will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses, and to ensure good communication between GXT (including the project leaders and the *Discoverer*), native communities along the coast, and subsistence hunters at sea.

Subsequent meetings with whaling captains, other community representatives, the AEWC, NSB, and any other parties to the plan will be held as necessary to negotiate the terms of the plan and to coordinate the planned seismic survey operation with subsistence hunting activity.

The proposed Plan of Cooperation may address the following:

- Operational agreement and communications procedures
- Where/when agreement becomes effective
- General communications scheme
- On-board Inupiat observer
- Conflict avoidance
- Seasonally sensitive areas
- Vessel navigation
- Air navigation
- Marine mammal monitoring activities
- Measures to avoid impacts to marine mammals
- Measures to avoid conflicts in areas of active whaling
- Emergency assistance
- Dispute resolution process

As noted above in § VIII, in the unlikely event that subsistence hunting or fishing is occurring within 5 km (3 mi) of the *Discoverer's* trackline, or within other situations inconsistent with the Conflict Avoidance Agreement, the airgun operations will be suspended until the vessel is >5 km away and otherwise in compliance with the CAA.

XIII. MONITORING AND REPORTING PLAN

> The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding...

GXT proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring, to satisfy the anticipated monitoring requirements of the USFWS and NMFS IHAs, and to meet any monitoring requirements agreed to as part of the Plan of Cooperation / Conflict Avoidance Agreement.

GXT's proposed Monitoring Plan is described below. GXT understands that this Monitoring Plan will be subject to review by NMFS and others, and that refinements may be required.

The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. GXT is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

Vessel-based Visual Monitoring

Vessel-based observers will monitor marine mammals near the seismic source vessel during all daytime hours and during any start ups of the airgun(s) at night. Airgun operations will be powered down or (if necessary) shut down when marine mammals are observed within, or about to enter, designated safety radii (see below) where there is a possibility of significant effects on hearing or other physical effects. Vessel-based MMOs will also watch for marine mammals near the seismic vessel for at least 30 min prior to the planned start of airgun operations after an extended shut down of the airgun. When feasible, observations will also be made during daytime periods without seismic operations (e.g., during transits).

During seismic operations when there is 24 hrs of daylight, four observers will be based aboard the vessel. As the number of hours of daylight decreases in the fall, the number of MMOs on the vessel will be reduced to three or two if full-time visual observations are not required at night. MMOs will be appointed by GXT with NMFS and USFWS concurrence. An Alaska native resident knowledgeable about the mammals and fish of the area is expected to be included as one of the team of MMOs aboard the *Discoverer*. At least one observer, and when practical two observers, will monitor marine mammals near the seismic vessel during ongoing daytime operations and any nighttime start ups of the airguns. (There will be no periods of total darkness until mid-August.) Use of two simultaneous observers will increase the proportion of the animals present near the source vessel that are detected. MMOs will normally be on duty in shifts of duration no longer than 4 hours. The *Discoverer* crew will be instructed by the MMOs onboard to assist in detecting marine mammals and implementing mitigation requirements (if practical). Before the start of the seismic survey the crew will be given additional instruction by the MMOs regarding implementation of mitigation measures.

The *Discoverer* is a suitable platform for marine mammal observations. Observations will be made from either the bridge or the flying bridge, which are greater than ~12 m (40 ft) above sea level. From the bridge, ~45° of the view will be obstructed directly to the stern (Appendix B). During daytime, the MMO(s) will scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), and with the naked eye. During any periods of darkness, NVDs will be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), if and when required. Laser rangefinding binoculars (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation; these are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to animals directly.

When marine mammals in the water are detected within or about to enter the designated safety radius, the airgun(s) will be powered down or shut down immediately. To assure prompt implementation of shut downs, multiple channels of communication between the MMOs and the airgun technicians will be established. During power downs and shut downs, the MMO(s) will continue to maintain watch to determine when the animal(s) are outside the safety radius. Airgun operations will not resume until the animal is outside the safety radius. Marine mammals will be considered to have cleared the safety radius if they are visually observed to have left the safety radius, or if they have not been seen within the radius for 15 min (pinnipeds or polar bears) or for 30 min (cetaceans).

All observations and airgun power downs or shut downs will be recorded in a standardized format. Data will be entered into a custom database using a notebook computer. The accuracy of the data entry will be verified by computerized validity data checks as the data are entered and by subsequent manual checking of the database. These procedures will allow initial summaries of data to be prepared during and shortly after the field program, and will facilitate transfer of the data to statistical, graphical, or other programs for further processing and archiving.

Results from the vessel-based observations will provide

1. The basis for real-time mitigation (airgun power or shut down).
2. Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
3. Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity.

Acoustic Verification and Modeling

Measurements of received sound levels as a function of distance and direction from the proposed airgun arrays will be made prior to, or at the beginning of the seismic survey. Results of this acoustic characterization/verification will be used to refine the pre-season estimates of safety and disturbance radii applicable to the sources during the remainder of seismic operations. A preliminary report of the measurement results concerning (at minimum) the 190 dB and 180 dB (rms) safety radii will be submitted shortly after data collection.

Additionally, more extensive modeling of the sounds that will be produced by the airgun array may be completed prior to the field season. The results of this modeling, if done, will be made available before the field season and the safety radii adjusted accordingly.

Aerial Surveys

GXT does not anticipate that aerial surveys will be required as a part of the monitoring program for Chukchi Sea seismic activities. Aerial surveys would be impractical in that they need to cover tremendous distances offshore.

Reporting

During the field season, brief progress reports will be provided to NMFS if called for by the IHA, on the schedule specified in the IHA.

A report on the preliminary results of the acoustic verification measurements, including as a minimum the measured 190 and 180 dB (rms) radii of the airgun sources, will be submitted shortly after collection of those measurements at the start of the field season. This report will specify the refinements to the safety radii that are proposed for adoption.

A report on GXT's activities and on the relevant monitoring and mitigation results will be submitted to NMFS within 90 days after the end of the cruise. The report will describe the operations that were conducted, the measured sound levels, and the cetaceans and seals that were detected near the operations. The report will be submitted to NMFS, providing full documentation of methods, results, and interpretation pertaining to all acoustic characterization work and vessel-based monitoring. The 90-day report will summarize the dates and locations of seismic operations, and all cetacean and seal sightings (dates, times, locations, activities, associated seismic survey activities). The number and circumstances of ramp ups, power downs, shutdowns, and other mitigation actions will be reported. The report will also include estimates of the amount and nature of potential "take" of cetaceans and seals by harassment or in other ways.

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

GXT will coordinate the planned marine mammal monitoring program associated with GXT's seismic survey with other parties that may be interested in this area and/or be conducting marine mammal studies or monitoring in the same region during operations. This is expected to include a number of other seismic surveys planned for the Chukchi Sea for parts of the 2006 open water season, each of which will presumably include a marine mammal monitoring component. At the request of the NMFS or other agencies with regulatory jurisdiction, GXT will participate with other parties in a combined research effort to document the distribution, abundance, and disturbance responses of marine mammals in the Chukchi Sea. Coordination of the planned monitoring program with research activities that NMFS, USFWS, and USGS may have scheduled will also be sought. The "open water peer/stakeholder review meeting" to be convened by NMFS in Anchorage in mid-April 2006, will provide a good opportunity to coordinate with those representing several of the relevant projects.

GXT will also coordinate with other applicable Federal, State and Borough agencies, and will comply with their requirements.

- LGL will contact the USFWS avian biologists regarding potential interaction with spectacled and Steller's eiders, or other bird species of "concern".
- LGL will make a request to the State of Alaska confirming that the project is in compliance with state and local Coastal Management Programs.
- GXT representatives will contact NSB Department of Wildlife Management biologists (Craig George and Robert Sudyam) concerning marine mammal and fisheries issues.
- LGL will coordinate with NOAA's Fisheries Biologist Larry Peltz concerning active fisheries in the study area and an EFH consultation.
- GXT representatives are coordinating with the Alaska Eskimo Whaling Commission and other representatives of subsistence hunters in coastal communities with regard to potential concerns about interactions with subsistence hunting, and a "Plan of Cooperation" / Conflict Avoidance Agreement is under negotiation.

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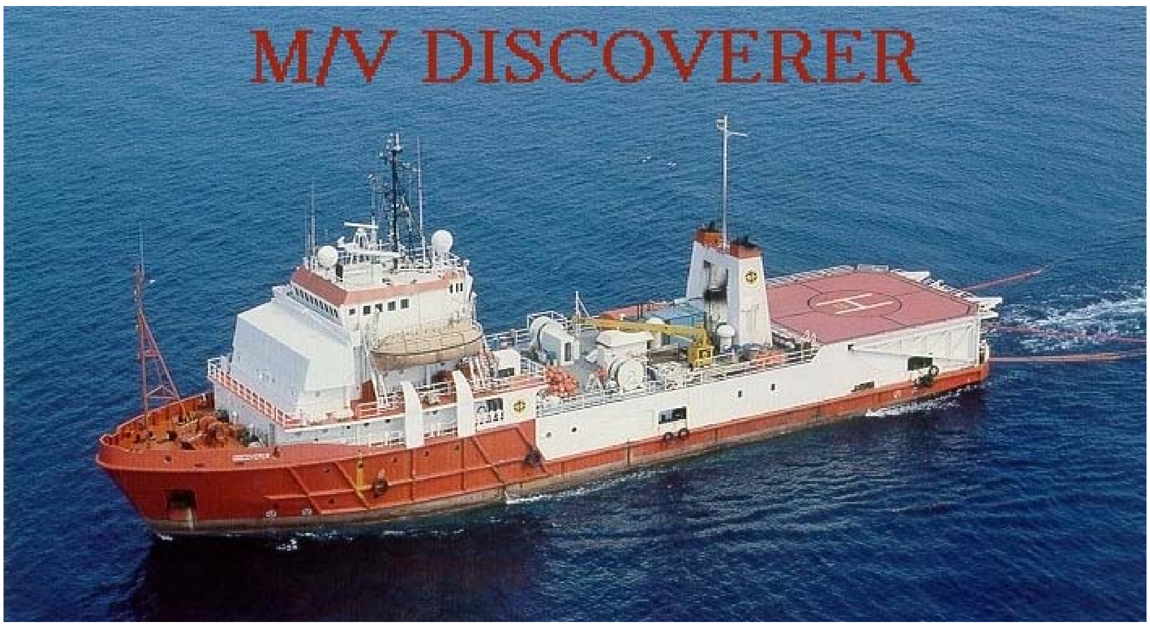
APPENDIX A:
VESSEL SPECIFICATION – DISCOVERER

M/V *Discoverer* is capable of doing both 2D and 3D seismic data acquisition work. For 3D seismic work the vessel can do dual source/dual streamer or dual source/three streamer operation providing high quality 2D and 3D seismic data for the industry. Features include a SYNTRAK 960-24 system configurable for multiple streamers. Options include real-time seismic processing, acoustic/laser source positioning, acoustic streamer positioning and onboard navigation. The following are general specifications for the vessel and seismic equipment on board.



REGISTRATION	
Built	1980-Converted 1988 (new seismic installation 1999)
Type	Seismic survey vessel, 2D or 3D
Official Number	711122
Owner	***Shanghai Offshore Petroleum Bureau***
Port of Registry	Nassau, Bahamas
Classifications	DNV + IAI SV SF ICE-C

DIMENSIONS	
Length	72.07m (236 feet)
Beam	16.0m (52 feet)
Draft	5.25m (17 feet)
Call Sign	C6CZ2
Tonnage	2747 Gross 689 Net (registered)
PROPULSION + CAPACITIES	
Main Engine	MLW-ALCO 251 V12x2 Total 5480 BHP
Propulsion	Direct drive, variable pitch propellers, 2 ea. (Liaaen/Hjelset ACG 77/600 CP.)
Bow Thruster	1 x 600 BHP Brunvoll, 1 X 450 BHP Brunvoll
Stern Thruster	2 x 600 BHP Brunvoll
Generators	BBC 485KVA x three 440/220V, 60 Hz driven by three Caterpillar 3412; TA 445 HP
Fuel Capacity	700 tons, approx. 50 days endurance
Water Capacity	350 tons, plus 2 tons / day water maker
Maximum Speed	12 knots
Cruising Speed	10 knots
Number of Berths	43 plus 1 hospital
COMMUNICATIONS	
INMARSAT- C MMSI	430966610
DSC ID	309666000
INMARSAT- A	Sperry Marine MCS2A Communication System Voice / Telex 1570326 Fax 1570735
INMARSAT-M	Voice 762309120/762309121 Fax 762309122 Data 762309123
Radios	406 EPIRB VHF DSC Radios MF/HF DSC Radios Portable VHF Helicopter Radios Radar Transponder
Navtex	ALDEN NavTex Receiver AE-900

BRIDGE/NAVIGATION EQUIPMENT	
Radar	Furuno FR 2110 (ARPA Display) Furuno FR 2010 (remote display)
Auto-pilot	Robertson AP9 MK II
Gyro-compass	Robertson RGC 11 Robertson RGC 11 (either used for survey)
Navigation	MX412 Professional DGPS Navigator
Echo-sounder	Simrad EA
LIFEBOATS / AUXILIARY CRAFT	
Lifesaving Equipment	2 x Harding Fully Enclosed Motor Lifeboats (total 120 persons) 4 x Life-rafts (total 62 persons)
Seismic Work Boat	
FRC	
HELIDECK	
Helideck	16m Diameter

ENERGY SOURCE

BOLT LONG LIFE AND TEXAS INSTRUMENT SLEEVE GUN HYBRID ARRAY

The vessel operates with a combination of TI Sleeve and BOLT Long Life airguns operating as interacting elements within several sub-arrays. This combination of guns provides a powerful source array with a broad flat spectrum from a relatively small number of individual units resulting in a good primary to bubble ratio. By using a limited number of units, overall system reliability is improved and production rates increased.

Some sleeve guns are deployed as interacting clusters and the inter element distances contribute to overall output of the sub-arrays. There may be up to six sub-arrays in all, deployed three per side, with typically a 17m longitudinal dimension and source centers adjustable to suit sub-surface spacing requirements.

The following specifications apply:

Airgun Manufacturer	Texas Instruments Sleeve Airguns Bolt Long Life Airguns
Number of Guns (Maximum)	96
Size of Guns	40 cu. in. to 600 cu. in.
Lateral Array Dimension	Variable to suit line spacing
Longitudinal Array Dimension	Approximately 17m
Maximum output (Typical)	Single Source 202 Bar m Dual Source 101 Bar m
Number of Hydro-phones for Gun Pulse Signature	1 per cluster or single gun
Array Towing Depth	4m to 8m (as specified)
Array Depth Detector	Depth sensors
Minimum Recycle Time	8 seconds
Timing Control	Automatic via TI magnetic sensors or Bolt pressure drop sensors GCS-90 gun controller and source hydro-phones monitor.

COMPRESSORS

The *Discoverer* is equipped with one LMF diesel driven air compressor and two LMF electrically driven. For the source arrays offered, this ensures a minimum of one spare large compressor during operations at normal shooting speeds up to 5.5 knots.

Compressor specifications	
Number of compressor	3
Compressor manufacturer	2 x LMF 300E electric driven (1040 cfm each) 1 x LMF 31-8D Diesel driven (1100 cfm)
Total air capacity in SCFM	3180 cfm
Normal Minimum Operating Pressure	2000psi
Spare air capacity for six sub-array	Minimum 33%

APPENDIX B:
THIRTY-SIX AIRGUN ARRAY DESCRIPTION [2]

The source vessel will tow along predetermined lines a 36-airgun array with a total discharge volume of 3320 in^3, as well as a hydrophone streamer 9 km long. Seismic pulses will be emitted at intervals of ~20 s and recorded. The 20 s spacing corresponds to a shot interval of ~46 m at the anticipated typical cruise speed of ~4-5 knots (8.3 km/h). The array will be towed at ~ 50 m from the stern of the *Discoverer* at a depth of ~8.5 m. As the airgun array is towed along the survey line, the towed hydrophone array receives the reflected signals and transfers the data to the on-board processing system.

The 36-airgun array will consist of 36 sleeve airguns (Fig. B1). The total discharge volume will be 3320 in^3.

36-Airgun Array Specifications

Energy source	36-sleeve airguns (8 × 40 in^3, 4 × 70 in^3, 4 × 80 in^3, 12 × 100 in^3, 8 × 150 in^3) firing every 20 s
Source output (downward)[3]	0-pk is 79.9 bar-m (258 dB re 1 μPa-m); pk-pk is 173 bar-m (265 dB re 1 μPa-m)
Towing depth of energy source	~8.5 m
Air discharge volume	3320 in^3
Dominant frequency components	0–256 Hz

Figures B2 and B3 show the predicted time and amplitude spectrum for the far-field signature of the 3320 in^3 36-airgun array. The signature of this array was computed using Gundalf array modeling suite (Gundalf 2002).

[3] All source levels are for a filter bandwidth of approximately 0-256 Hz.

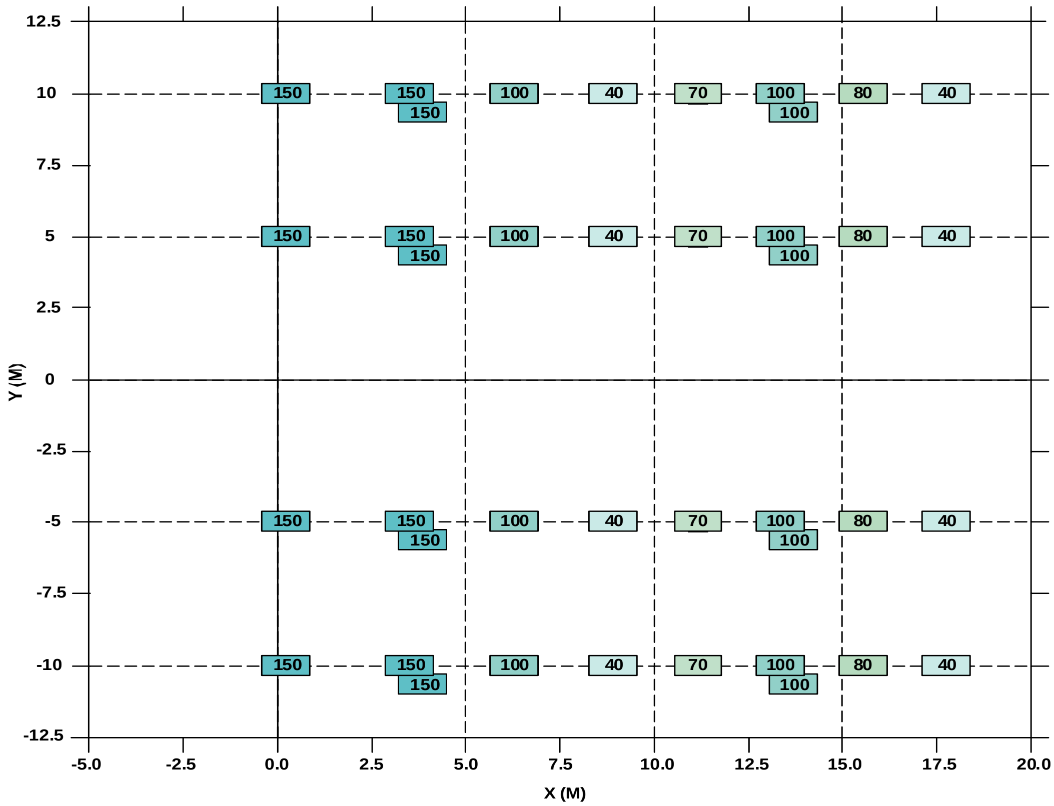


FIGURE B1. The spacing and configuration of the 36-airgun array to be towed behind the *Discoverer* during the proposed Chukchi Sea Survey, between 15 June and 30 November 2006. Total discharge value is indicated within each airgun symbol. Measurements are in meters.

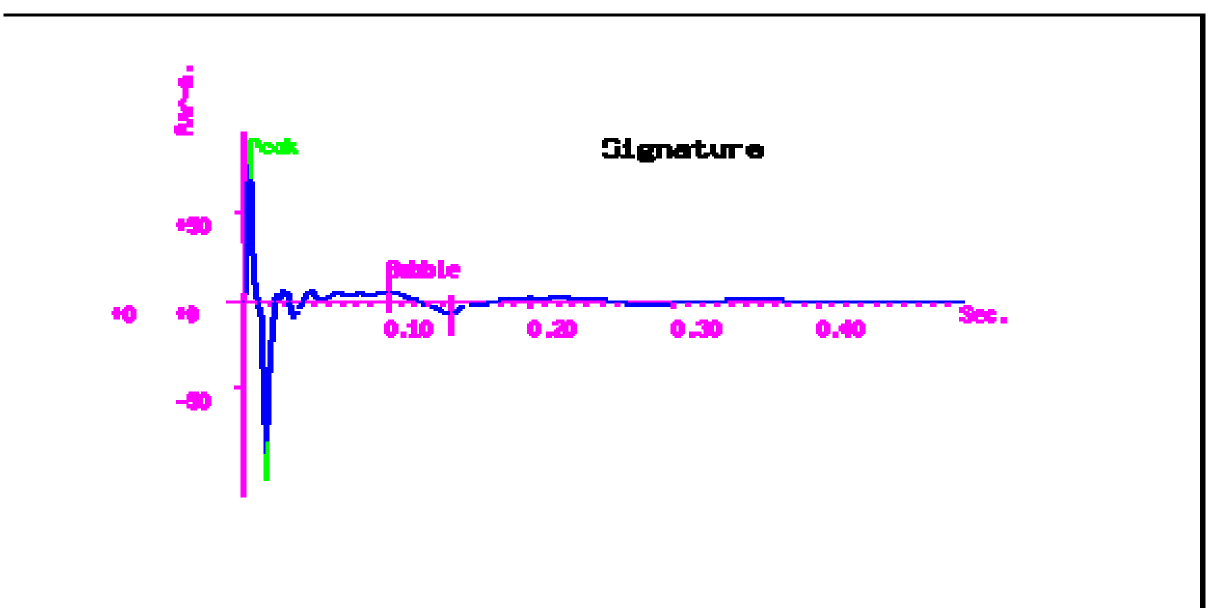


FIGURE B2. Far-field source signature for 40 G. gun 3980 in^3 array to be used by GXT in Chukchi Sea 2006.

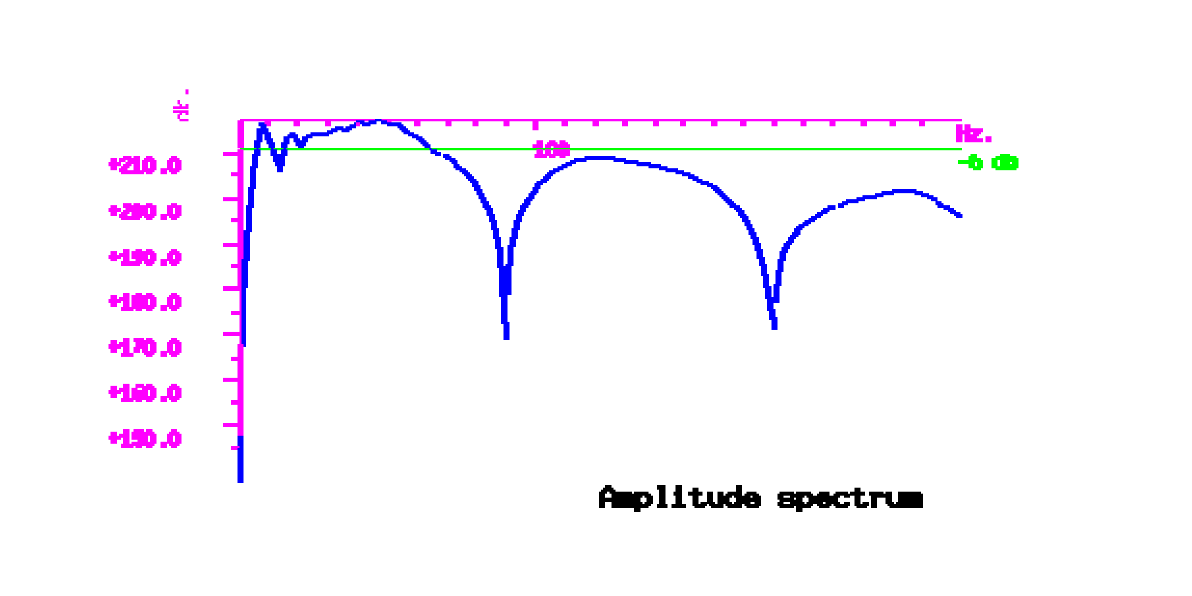


FIGURE B3. Far-field source amplitude spectrum for 40 G. gun 3980 in^3 array to be used by GXT in Chukchi Sea, 2006.

APPENDIX C:
REVIEW OF POTENTIAL IMPACTS OF AIRGUN SOUNDS ON MARINE MAMMALS [4]

The following subsections review relevant information concerning the potential effects of airgun sounds on marine mammals. This information is included here as background for the briefer summary of this topic included in § IV of the EA. This background material is little changed from corresponding subsections included in IHA applications and EAs submitted to NMFS for previous NSF-funded seismic surveys from 2003 to date. Much of this information has also been included in varying formats in other reviews, assessments, and regulatory applications prepared by LGL Ltd., environmental research associates. Because this review is intended to be of general usefulness, it includes references to types of marine mammals that will not be found in some specific regions.

(a) Categories of Noise Effects

The effects of noise on marine mammals are highly variable, and can be categorized as follows (based on Richardson et al. 1995):

1. The noise may be too weak to be heard at the location of the animal, i.e., lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both;
2. The noise may be audible but not strong enough to elicit any overt behavioral response, i.e., the mammals may tolerate it;
3. The noise may elicit behavioral reactions of variable conspicuousness and variable relevance to the well being of the animal; these can range from subtle effects on respiration or other behaviors (detectable only by statistical analysis) to active avoidance reactions;
4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist; the latter is most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat;
5. Any man-made noise that is strong enough to be heard has the potential to reduce (mask) the ability of marine mammals to hear natural sounds at similar frequencies, including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or (at high latitudes) ice noise. However, intermittent airgun or sonar pulses could cause masking for only a small proportion of the time, given the short duration of these pulses relative to the inter-pulse intervals;
6. Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity, or other physical effects. Received sound levels must far exceed the animal's hearing threshold for any temporary threshold shift to occur. Received levels must be even higher for a risk of permanent hearing impairment.

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[4] By **W. John Richardson** and **Valerie D. Moulton**, LGL Ltd., environmental research associates. Revised January 2006 by Meike Holst and W. John Richardson, LGL Ltd.

(b) Hearing Abilities of Marine Mammals

The hearing abilities of marine mammals are functions of the following (Richardson et al. 1995; Au et al. 2000):

1. Absolute hearing threshold at the frequency in question (the level of sound barely audible in the absence of ambient noise). The "best frequency" is the frequency with the lowest absolute threshold.
2. Critical ratio (the signal-to-noise ratio required to detect a sound at a specific frequency in the presence of background noise around that frequency).
3. The ability to localize sound direction at the frequencies under consideration.
4. The ability to discriminate among sounds of different frequencies and intensities.

Marine mammals rely heavily on the use of underwater sounds to communicate and to gain information about their surroundings. Experiments also show that they hear and may react to many man-made sounds including sounds made during seismic exploration.

Toothed Whales

Hearing abilities of some toothed whales (odontocetes) have been studied in detail (reviewed in Chapter 8 of Richardson et al. [1995] and in Au et al. [2000]). Hearing sensitivity of several species has been determined as a function of frequency. The small to moderate-sized toothed whales whose hearing has been studied have relatively poor hearing sensitivity at frequencies below 1 kHz, but extremely good sensitivity at, and above, several kHz. There are very few data on the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm and beaked whales. However, Mann et al. (2005) report that a Gervais' beaked whale showed evoked potentials from 5 to 80 kHz, with the best sensitivity at 80 kHz.

Despite the relatively poor sensitivity of small odontocetes at the low frequencies that contribute most of the energy in pulses of sound from airgun arrays, the sounds are sufficiently strong that their received levels sometimes remain above the hearing thresholds of odontocetes at distances out to several tens of kilometers (Richardson and Würsig 1997). However, there is no evidence that small odontocetes react to airgun pulses at such long distances, or even at intermediate distances where sound levels are well above the ambient noise level (see below).

The multibeam bathymetric sonars operated from oceanographic vessels to survey deep areas emit pulsed sounds at 12–15.5 kHz. Those frequencies are within or near the range of best sensitivity of many odontocetes. Thus, sound pulses from the multibeam sonar will be readily audible to these animals when they are within the narrow angular extent of the transmitted sound beam. Some vessels operate higher frequency (e.g., 24–455 kHz) multibeam sonars designed to map shallower waters, and some of those will also be audible to odontocetes.

Baleen Whales

The hearing abilities of baleen whales have not been studied directly. Behavioral and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). Baleen whales also reacted to sonar sounds at 3.1 kHz and other sources centered at 4 kHz (see Richardson et al. 1995 for a review). Frankel (2005) noted that gray whales reacted to a 21–25 kHz whale-finding sonar. Some baleen whales react to pinger sounds up to 28 kHz, but not to pingers or sonars emitting sounds at 36 kHz or above (Watkins 1986). In addition, baleen whales produce sounds at frequencies up to 8 kHz and, for humpbacks, to >15 kHz (Au et al. 2001). The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds (Ketten 1991, 1992, 1994, 2000). The absolute sound levels that they can detect below 1 kHz are probably limited by increasing levels of natural ambient noise at decreasing frequencies. Ambient noise energy is higher at low frequencies than at mid frequencies. At frequencies below 1 kHz, natural ambient levels tend to increase with decreasing frequency.

The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small toothed whales that have been studied directly. Thus, baleen whales are likely to hear airgun pulses farther away than can small toothed whales and, at closer distances, airgun sounds may seem more prominent to baleen than to toothed whales. However, baleen whales have commonly been seen well within the distances where seismic (or sonar) sounds would be detectable and yet often show no overt reaction to those sounds. Behavioral responses by baleen whales to seismic pulses have been documented, but received levels of pulsed sounds necessary to elicit behavioral reactions are typically well above the minimum detectable levels (Malme et al. 1984, 1988; Richardson et al. 1986, 1995; McCauley et al. 2000a; Johnson 2002).

Pinnipeds

Underwater audiograms have been obtained using behavioral methods for three species of phocinid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995: 211*ff*; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002). In comparison with odontocetes, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, better auditory sensitivity at low frequencies, and poorer sensitivity at the best frequency.

At least some of the phocid (hair) seals have better sensitivity at low frequencies (≤1 kHz) than do odontocetes. Below 30–50 kHz, the hearing thresholds of most species tested are essentially flat down to about 1 kHz, and range between 60 and 85 dB re 1 µPa. Measurements for a harbor seal indicate that, below 1 kHz, its thresholds deteriorate gradually to ~97 dB re 1 µPa at 100 Hz (Kastak and Schusterman 1998). The northern elephant seal appears to have better underwater sensitivity than the harbor seal, at least at low frequencies (Kastak and Schusterman 1998, 1999).

For the otariid (eared) seals, the high frequency cutoff is lower than for phocinids, and sensitivity at low frequencies (e.g., 100 Hz) is poorer than for hair seals (harbor or elephant seal).

The underwater hearing of a walrus has been measured at frequencies from 125 Hz to 15 kHz (Kastelein et al. 2002). The range of best hearing was from 1–12 kHz, with maximum sensitivity (67 dB re 1 µPa) occurring at 12 kHz (Kastelein et al. 2002).

Sirenians

The West Indian manatee can apparently detect sounds from 15 Hz to 46 kHz, based on use of behavioral testing methods (Gerstein et al. 1999). Thus, manatees may hear, or at least detect, sounds in the low-frequency range where most seismic energy is released. It is possible that they are able to feel these low-frequency sounds using vibrotactile receptors or because of resonance in body cavities or bone conduction.

Based on measurements of evoked potentials, manatee hearing is apparently best around 1–1.5 kHz (Bullock et al. 1982). However, behavioral testing suggests their best sensitivity is at 6–20 kHz (Gerstein et al. 1999). The ability to detect high frequencies may be an adaptation to shallow water, where the propagation of low frequency sound is limited (Gerstein et al. 1999).

(c) Characteristics of Airgun Pulses

Airguns function by venting high-pressure air into the water. The pressure signature of an individual airgun consists of a sharp rise and then fall in pressure, followed by several positive and negative pressure excursions caused by oscillation of the resulting air bubble. The sizes, arrangement, and firing times of the individual airguns in an array are designed and synchronized to suppress the pressure oscillations subsequent to the first cycle. The resulting downward-directed pulse has a duration of only 10 to 20 ms, with only one strong positive and one strong negative peak pressure (Caldwell and Dragoset 2000). Most energy emitted from airguns is at relatively low frequencies. For example, typical high-energy airgun arrays emit most energy at 10–120 Hz. However, the pulses contain some energy up to 500–1000 Hz and above (Goold and Fish 1998). The pulsed sounds associated with seismic exploration have higher peak levels than other industrial sounds to which whales and other marine mammals are routinely exposed. The only sources with higher or comparable effective source levels are explosions.

The peak-to-peak source levels of the 2- to 20-airgun arrays used by Lamont-Doherty Earth Observatory (L-DEO) from the R/V *Maurice Ewing* during previous projects ranged from 236 to 263 dB re 1 μPa at 1 m, considering the frequency band up to about 250 Hz. The peak-to-peak source level for the 36-airgun array to be used from the *Langseth* is 265 dB. These are the nominal source levels applicable to downward propagation. The effective source levels for horizontal propagation are lower than those for downward propagation when numerous airguns spaced apart from one another use used. The only man-made sources with effective source levels as high as (or higher than) a large array of airguns are explosions and high-power sonars operating near maximum power.

Several important mitigating factors need to be kept in mind. *(1)* Airgun arrays produce intermittent sounds, involving emission of a strong sound pulse for a small fraction of a second followed by several seconds of near silence. In contrast, some other sources produce sounds with lower peak levels, but their sounds are continuous or discontinuous but continuing for much longer durations than seismic pulses. *(2)* Airgun arrays are designed to transmit strong sounds downward through the seafloor, and the amount of sound transmitted in near-horizontal directions is considerably reduced. Nonetheless, they also emit sounds that travel horizontally toward non-target areas. *(3)* An airgun array is a distributed source, not a point source. The nominal source level is an estimate of the sound that would be measured from a theoretical point source emitting the same total energy as the airgun array. That figure is useful in calculating the expected received levels in the far field, i.e., at moderate and long distances. Because the airgun array is not a single point source, there is no one location within the near field (or anywhere else) where the received level is as high as the nominal source level.

The strengths of airgun pulses can be measured in different ways, and it is important to know which method is being used when interpreting quoted source or received levels. Geophysicists usually quote peak-to-peak levels, in bar-meters or (less often) dB re 1 μPa · m. The peak (= zero-to-peak) level for the same pulse is typically about 6 dB less. In the biological literature, levels of received airgun pulses are often described based on the “average” or “root-mean-square” (rms) level, where the average is calculated over the duration of the pulse. The rms value for a given airgun pulse is typically about 10 dB lower than the peak level, and 16 dB lower than the peak-to-peak value (Greene 1997; McCauley et al. 1998, 2000a). A fourth measure that is sometimes used is the energy, or Sound Exposure Level (SEL), in dB re 1 $\mu Pa^2 \cdot s$. Because the pulses are <1 s in duration, the numerical value of the energy is lower than the rms pressure level, but the units are different. Because the level of a given pulse will differ substantially depending on which of these measures is being applied, it is important to be aware which measure is in use when interpreting any quoted pulse level. In the past, NMFS has commonly referred to rms levels when discussing levels of pulsed sounds that might "harass" marine mammals.

Seismic sound received at any given point will arrive via a direct path, indirect paths that include reflection from the sea surface and bottom, and often indirect paths including segments through the bottom sediments. Sounds propagating via indirect paths travel longer distances and often arrive later than sounds arriving via a direct path. (However, sound traveling in the bottom may travel faster than that in the water, and thus may, in some situations, arrive slightly earlier than the direct arrival despite traveling a greater distance.) These variations in travel time have the effect of lengthening the duration of the received pulse, or may cause two or more received pulses from a single emitted pulse. Near the source, the predominant part of a seismic pulse is about 10–20 ms in duration. In comparison, the pulse duration as received at long horizontal distances can be much greater. For example, for one airgun array operating in the Beaufort Sea, pulse duration was about 300 ms at a distance of 8 km, 500 ms at 20 km, and 850 ms at 73 km (Greene and Richardson 1988).

Another important aspect of sound propagation is that received levels of low-frequency underwater sounds diminish close to the surface because of pressure-release and interference phenomena that occur at and near the surface (Urick 1983; Richardson et al. 1995). Paired measurements of received airgun sounds at depths of 3 vs. 9 or 18 m have shown that received levels are typically several decibels lower at 3 m (Greene and Richardson 1988). For a mammal whose auditory organs are within 0.5 or 1 m of the surface, the received level of the predominant low-frequency components of the airgun pulses would be further reduced. In deep water, the received levels at deep depths can be considerably higher than those at relatively shallow (e.g., 18 m) depths at the same horizontal distance from the airguns (Tolstoy et al. 2004a,b).

Pulses of underwater sound from open-water seismic exploration are often detected 50–100 km from the source location, even during operations in nearshore waters (Greene and Richardson 1988; Burgess and Greene 1999). At those distances, the received levels are low, <120 dB re 1 μPa on an approximate rms basis. However, faint seismic pulses are sometimes detectable at even greater ranges (e.g., Bowles et al. 1994; Fox et al. 2002). Considerably higher levels can occur at distances out to several kilometers from an operating airgun array.

(d) Masking Effects of Seismic Surveys

Masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004). Although there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), more recent studies reported that sperm whales continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocetes, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are airgun sounds.

Most of the energy in the sound pulses emitted by airgun arrays is at low frequencies, with strongest spectrum levels below 200 Hz and considerably lower spectrum levels above 1000 Hz. These low frequencies are mainly used by mysticetes, but generally not by odontocetes, pinnipeds, or sirenians.

An industrial sound source will reduce the effective communication or echolocation distance only if its frequency is close to that of the marine mammal signal. If little or no overlap occurs between the industrial noise and the frequencies used, as in the case of many marine mammals vs. airgun sounds, communication and echolocation are not expected to be disrupted. Furthermore, the discontinuous nature of seismic pulses makes significant masking effects unlikely even for mysticetes.

A few cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, or to shift their peak frequencies in response to strong sound signals (Dahlheim 1987; Au 1993; Lesage et al. 1999; Terhune 1999; Nieukirk et al. 2005; Parks et al. 2005; reviewed in Richardson et al. 1995:233*ff*, 364*ff*). These studies involved exposure to other types of anthropogenic sounds, not seismic pulses, and it is not known whether these types of responses ever occur upon exposure to seismic sounds. If so, these adaptations, along with directional hearing and preadaptation to tolerate some masking by natural sounds (Richardson et al. 1995), would all reduce the importance of masking.

(e) Disturbance by Seismic Surveys

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. In the terminology of the 1994 amendments to the MMPA, seismic noise could cause "Level B" harassment of certain marine mammals. Level B harassment is defined as "...disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

There has been debate regarding how substantial a change in behavior or mammal activity is required before the animal should be deemed to be "taken by Level B harassment". NMFS has stated that

> "…a simple change in a marine mammal's actions does not always rise to the level of disruption of its behavioral patterns. … If the only reaction to the [human] activity on the part of the marine mammal is within the normal repertoire of actions that are required to carry out that behavioral pattern, NMFS considers [the human] activity not to have caused a disruption of the behavioral pattern, provided the animal's reaction is not otherwise significant enough to be considered disruptive due to length or severity. Therefore, for example, a short-term change in breathing rates or a somewhat shortened or lengthened dive sequence that are within the animal's normal range and that do not have any biological significance (i.e., do no disrupt the animal's overall behavioral pattern of breathing under the circumstances), do not rise to a level requiring a small take authorization." (NMFS 2001, p. 9293).

Based on this guidance from NMFS, we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Even with this guidance, there are difficulties in defining what marine mammals should be counted as "taken by harassment". For many species and situations, we do not have detailed information about their reactions to noise, including reactions to seismic (and sonar) pulses. Behavioral reactions of marine mammals to sound are difficult to predict. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react to an underwater sound by changing its behavior or moving a small distance, the impacts of the change may not be significant to the individual let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be significant. Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. In most cases, this likely overestimates the numbers of marine mammals that are affected in some biologically important manner.

The definitions of “taking” in the U.S. MMPA, and its applicability to various activities, were slightly altered in November 2003 for military and federal scientific research activities. Also, NMFS is proposing to replace current Level A and B harassment criteria with guidelines based on exposure characteristics that are specific to species and sound types. In 2005, public meetings were conducted across the nation to consider the impact of implementing new criteria for what constitutes a “take” of marine mammals. Currently, a committee of specialists on noise impact issues is drafting recommendations for new impact criteria, as summarized by Gentry et al. (2004); those recommendations are expected to be made public soon. Thus, for projects subject to U.S. jurisdiction, changes in procedures may be required in the near future.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, and small toothed whales.

Baleen Whales

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. Some studies and reviews on this topic are as follows: Malme et al. 1984, 1985, 1988; Richardson et al. 1986, 1995, 1999; Ljungblad et al. 1988; Richardson and Malme 1993; McCauley et al. 1998, 2000a; Miller et al. 1999; 2005; Gordon et al. 2004; Moulton and Miller in press). There is also evidence that baleen whales will often show avoidance of a small airgun source or upon onset of a ramp up when just one airgun is firing. Experiments with a single airgun showed that bowhead, humpback and gray whales all showed localized avoidance to a single airgun of 20–100 in^3 (Malme et al. 1984, 1985, 1986, 1987, 1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b)

Prior to the late 1990s, it was thought that bowhead, gray, and humpback whales all begin to show strong avoidance reactions to seismic pulses at received levels of ~160 to 170 dB re 1 μPa rms, but that subtle behavioral changes sometimes become evident at somewhat lower received levels. More recent studies have shown that some species of baleen whales (bowheads and humpbacks in particular) may show strong avoidance at received levels lower than 160–170 dB re 1 μPa rms. The observed avoidance reactions involved movement away from feeding locations or statistically significant deviations in the whales’ direction of swimming and/or migration corridor as they approached or passed the sound sources. In the case of the migrating whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals—they simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Humpback Whales.—McCauley et al. (1998, 2000a) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-airgun 2678-in^3 array, and to a single 20 in^3

airgun with source level 227 dB re 1 μPa·m (p-p). They found that the overall distribution of humpbacks migrating through their study area was unaffected by the full-scale seismic program. McCauley et al. (1998) did, however, document localized avoidance of the array and of the single airgun. Avoidance reactions began at 5–8 km from the array, and those reactions kept most pods about 3–4 km from the operating seismic boat. Observations were made from the seismic vessel, from which the maximum viewing distance was listed as 14 km. Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. Mean avoidance distance from the airgun corresponded to a received sound level of 140 dB re 1 μPa rms; this was the level at which humpbacks started to show avoidance reactions to an approaching airgun. The standoff range, i.e., the closest point of approach (CPA) of the airgun to the whales, corresponded to a received level of 143 dB rms. The initial avoidance response generally occurred at distances of 5–8 km from the airgun array and 2 km from the single airgun. However, some individual humpback whales, especially males, approached within distances 100–400 m, where the maximum received level was 179 dB re 1 μPa rms.

Humpback whales summering in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64-L (100 in^3) airgun (Malme et al. 1985). Some humpbacks seemed "startled" at received levels of 150–169 dB re 1 μPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis.

Bowhead Whales.—Bowhead whales on their summering grounds in the Canadian Beaufort Sea showed no obvious reactions to pulses from seismic vessels at distances of 6–99 km and received sound levels of 107–158 dB on an approximate rms basis (Richardson et al. 1986); their general activities were indistinguishable from those of a control group. However, subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon statistical analysis. Bowheads usually did show strong avoidance responses when seismic vessels approached within a few kilometers (~3–7 km) and when received levels of airgun sounds were 152–178 dB (Richardson et al. 1986, 1995; Ljungblad et al. 1988). In one case, bowheads engaged in near-bottom feeding began to turn away from a 30-airgun array with a source level of 248 dB re 1 μPa·m at a distance of 7.5 km, and swam away when it came within ~2 km. Some whales continued feeding until the vessel was 3 km away. This work and a more recent study by Miller et al. (2005) show that feeding bowhead whales tend to tolerate higher sound levels than migrating bowhead whales before showing an overt change in behavior. The feeding whales may be affected by the sounds, but the need to feed may reduce the tendency to move away.

Migrating bowhead whales in the Alaskan Beaufort Sea seem more responsive to noise pulses from a distant seismic vessel than are summering bowheads. In 1996–98, a partially-controlled study of the effect of Ocean Bottom Cable (OBC) seismic surveys on westward-migrating bowheads was conducted in late summer and autumn in the Alaskan Beaufort Sea (Miller et al. 1999; Richardson et al. 1999). Aerial surveys showed that some westward-migrating whales avoided an active seismic survey boat by 20–30 km, and that few bowheads approached within 20 km. Received sound levels at those distances were only 116–135 dB re 1 μPa (rms). Some whales apparently began to deflect their migration path when still as much as ~35 km away from the airguns. At times when the airguns were not active, many bowheads moved into the area close to the inactive seismic vessel. Avoidance of the area of seismic operations did not persist beyond 12–24 h after seismic shooting stopped.

Gray Whales.—Malme et al. (1986, 1988) studied the responses of feeding eastern gray whales to pulses from a single 100 in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 µPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Malme at al. (1986) estimated that an average pressure level of 173 dB occurred at a range of 2.6–2.8 km from an airgun array with a source level of 250 dB (0-pk) in the northern Bering Sea. These findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast. Malme and Miles (1985) concluded that, during migration, changes in swimming pattern occurred for received levels of about 160 dB re 1 µPa and higher, on an approximate rms basis. The 50% probability of avoidance was estimated to occur at a CPA distance of 2.5 km from a 4000-in^3 array operating off central California. This would occur at an average received sound level of about 170 dB (rms). Some slight behavioral changes were noted at received sound levels of 140 to 160 dB (rms).

There was no indication that western gray whales exposed to seismic noise were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001. However, there were indications of subtle behavioral effects and (in 2001) localized avoidance by some individuals (Johnson 2002; Weller et al. 2002).

Rorquals.—Blue, sei, fin, and minke whales have occasionally been reported in areas ensonified by airgun pulses. Sightings by observers on seismic vessels off the U.K. from 1997 to 2000 suggest that, at times of good sightability, numbers of rorquals seen are similar when airguns are shooting and not shooting (Stone 2003). Although individual species did not show any significant displacement in relation to seismic activity, all baleen whales combined were found to remain significantly further from the airguns during shooting compared with periods without shooting (Stone 2003). Baleen whale pods sighted from the ship were found to be at a median distance of ~1.6 km from the array during shooting and 1.0 km during periods without shooting (Stone 2003). Baleen whales, as a group, made more frequent alterations of course (usually away from the vessel) during shooting compared with periods of no shooting (Stone 2003). In addition, fin/sei whales were less likely to remain submerged during periods of seismic shooting (Stone 2003).

Discussion and Conclusions.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, studies done since the late 1990s of humpback and especially migrating bowhead whales, show that reactions, including avoidance, sometimes extend to greater distances than documented earlier. Avoidance distances often exceed the distances at which boat-based observers can see whales, so observations from the source vessel are biased.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioral changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 µPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses diminish to these levels at distances ranging from 4.5 to 14.5 km from the source. A substantial proportion of the baleen whales within this distance range may show avoidance or other strong disturbance reactions to the operating airgun array. In the case of migrating bowhead whales, avoidance extends to larger distances and lower received sound levels.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. Gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A in Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years. Bowheads were often seen in summering areas where seismic exploration occurred in preceding summers (Richardson et al. 1987). They also have been observed over periods of days or weeks in areas repeatedly ensonified by seismic pulses. However, it is not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas.

Toothed Whales

Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales, and none similar in size and scope to the studies of humpback, bowhead, and gray whales mentioned above. However, systematic work on sperm whales is underway.

Delphinids.—Seismic operators sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of operating seismic vessels (e.g., Stone 2003; Moulton and Miller in press). Studies that have reported cases of small toothed whales close to the operating airguns include Duncan (1985), Arnold (1996), and Stone (2003). When a 3959 in^3, 18-airgun array was firing off California, toothed whales behaved in a manner similar to that observed when the airguns were silent (Arnold 1996). Most, but not all, dolphins often seemed to be attracted to the seismic vessel and floats, and some rode the bow wave of the seismic vessel regardless of whether the airguns were firing.

Goold (1996a,b,c) studied the effects on common dolphins, *Delphinus delphis*, of 2D seismic surveys in the Irish Sea. Passive acoustic surveys were conducted from the "guard ship" that towed a hydrophone 180-m aft. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1-km radius from the airguns (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, and were not attributable to seismic surveys (Goold 1996a,b,c).

A monitoring study of summering belugas exposed to a seismic survey found that sighting rates, as determined by aerial surveys, were significantly lower at distances of 10–20 compared with 20–30 km from the operating airgun array (Miller et al. 2005). The low number of sightings from the vessel seemed to confirm a large avoidance response to the 2250 in^3 airgun array. The apparent displacement effect on belugas extended farther than has been shown for other small odontocetes exposed to airgun pulses.

Observers stationed on seismic vessels operating off the United Kingdom from 1997–2000 have provided data on the occurrence and behavior of various toothed whales exposed to seismic pulses (Stone 2003; Gordon et al. 2004). Dolphins of various species often showed more evidence of avoidance of operating airgun arrays than has been reported previously for small odontocetes. Sighting rates of white-sided dolphins, white-beaked dolphins, *Lagenorhynchus* spp., and all small odontocetes combined were significantly lower during periods of shooting. Except for pilot whales, all of the small odontocete species tested, including killer whales, were found to be significantly farther from large airgun arrays during periods of shooting compared with periods of no shooting. Pilot whales showed few reactions to seismic activity. The displacement of the median distance from the array was ~0.5 km or more for most species groups. Killer whales appeared to be more tolerant of seismic shooting in deeper waters.

For all small odontocete species, except pilot whales, that were sighted during seismic surveys off the U.K. in 1997–2000, the numbers of positive interactions with the survey vessel (e.g., bow-riding, approaching the vessel) were significantly fewer during periods of shooting. All small odontocetes combined showed more negative interactions (e.g., avoidance) during periods of shooting. Small odontocetes, including white-beaked dolphins, *Lagenorhynchus* spp., and other dolphin species, showed a tendency to swim faster during periods with seismic shooting; *Lagenorhynchus* spp. were also observed to swim more slowly during periods without shooting. Significantly fewer white-beaked dolphins, *Lagenorhynchus* spp. and pilot whales traveled towards the vessel and/or more were traveling away from the vessel during periods of shooting.

During two NSF-funded L-DEO seismic surveys, using a large 20 airgun array (~7000 in^3), sighting rates of delphinids were lower and initial sighting distances were farther away from the vessel during seismic than non-seismic periods (Smultea et al. 2004; Holst et al. 2005a). Monitoring results during a seismic survey in the Southeast Caribbean showed that the mean CPA of delphinids during seismic operations was 991 m compared with 172 m when the airguns were not operational (Smultea et al. 2004). Surprisingly, nearly all acoustic encounters (including delphinids and sperm whales) were made when the airguns were operating (Smultea et al. 2004). Although the number of sightings during monitoring of a seismic survey off the Yucatán Peninsula, Mexico, was small (n = 19), the results showed that the mean CPA of delphinids during seismic operations was 472 m compared with 178 m when the airguns were not operational (Holst et al. 2005a). The acoustic detection rates were nearly 5 times higher during non-seismic compared with seismic operations (Holst et al. 2005a).

Reactions of toothed whales to a single airgun or other small airgun source are not well documented, but do not seem to be very substantial (e.g., Stone 2003). Results from three NSF-funded L-DEO seismic surveys using small arrays (up to 3 GI guns and 315 in^3) were inconclusive. During a survey in the Eastern Tropical Pacific (Holst et al. 2005b) and in the Northwest Atlantic (Haley and Koski 2004), detection rates were slightly lower during seismic compared to non-seismic periods. However, mean CPAs were closer during seismic during one cruise (Holst et al. 2005b), and greater during the other cruise (Haley and Koski 2004). Interpretation of the data was confounded by the fact that survey effort and/or number of sightings during non-seismic periods during both surveys was small. Results from another small-array survey in southeast Alaska were even more variable (MacLean and Koski 2005).

Captive bottlenose dolphins and beluga whales exhibited changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). Finneran et al. (2002) exposed a captive bottlenose dolphin and beluga to single impulses from a water gun (80 in^3). As compared with airgun pulses, water gun impulses were expected to contain proportionally more energy at higher frequencies because there is no significant gas-filled bubble, and thus little low-frequency bubble-pulse energy (Hutchinson and Detrick 1984). The captive animals sometimes vocalized after exposure and exhibited reluctance to station at the test site where subsequent exposure to impulses would be implemented (Finneran et al. 2002). Similar behaviors were exhibited by captive bottlenose dolphins and a beluga exposed to single underwater pulses designed to simulate those produced by distant underwater explosions (Finneran et al. 2000). It is uncertain what relevance these observed behaviors in captive, trained marine mammals exposed to single sound pulses may have to free-ranging animals exposed to multiple pulses. In any event, the animals tolerated rather high received levels of sound (pk-pk level >200 dB re 1 μPa) before exhibiting the aversive behaviors mentioned above.

Observations of odontocete responses (or lack of responses) to noise pulses from underwater explosions (as opposed to airgun pulses) may be relevant as an indicator of odontocete responses to very strong noise pulses. During the 1950s, small explosive charges were dropped into an Alaskan river in attempts to scare belugas away from salmon. Success was limited (Fish and Vania 1971; Frost et al. 1984). Small explosive charges were "not always effective" in moving bottlenose dolphins away from sites in the Gulf of Mexico where larger demolition blasts were about to occur (Klima et al. 1988). Odontocetes may be attracted to fish killed by explosions, and thus attracted rather than repelled by "scare" charges. Captive false killer whales showed no obvious reaction to single noise pulses from small (10 g) charges; the received level was ~185 dB re 1 μPa (Akamatsu et al. 1993). Jefferson and Curry (1994) reviewed several additional studies that found limited or no effects of noise pulses from small explosive charges on killer whales and other odontocetes. Aside from the potential for temporary threshold shift (TTS), the tolerance to these charges may indicate a lack of effect or the failure to move away may simply indicate a stronger desire to eat, regardless of circumstances.

Phocinids.—Porpoises, like delphinids, show variable reactions to seismic operations. Calambokidis and Osmek (1998) noted that Dall's porpoises observed during a survey with a 6000 in^3, 12–16-airgun array tended to head away from the boat. Similarly, during seismic surveys off the U.K. in 1997–2000, significantly fewer harbor porpoises traveled towards the vessel and/or more were traveling away from the vessel during periods of shooting (Stone 2003). During both an experimental and a commercial seismic survey, Gordon et al. (1998 *in* Gordon et al. 2004) noted that acoustic contact rates for harbor porpoises were similar during seismic and non-seismic periods.

Beaked Whales.—There are no specific data on the behavioral reactions of beaked whales to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986). It is likely that these beaked whales would normally show strong avoidance of an approaching seismic vessel, but this has not been documented explicitly. Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels (Reeves et al. 1993; Hooker et al. 2001). However, those vessels were not emitting airgun pulses.

There are increasing indications that some beaked whales tend to strand when naval exercises, including sonar operation, are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; Jepson et al. 2003; see also the "Strandings and Mortality" subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales would ever react similarly to seismic surveys is unknown. Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents. There was a stranding of Cuvier's beaked whales in the Gulf of California (Mexico) in Sept. 2002 when the R/V *Maurice Ewing* was conducting a seismic survey in the general area (e.g., Malakoff 2002). Another stranding of Cuvier's beaked whales in the Galapagos occurred during a seismic survey in April 2000; however "There is no obvious mechanism that bridges the distance between this source and the stranding site" (Gentry [ed.] 2002). The evidence with respect to seismic surveys and beaked whale strandings is inconclusive, and NMFS has not established a link between the Gulf of California stranding and the seismic activities (Hogarth 2002).

Sperm Whales.—All three species of sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds (e.g., Richardson et al. 1995; Würsig et al. 1998). Thus, it is to be expected that they would tend to avoid an operating seismic survey vessel. There are some limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some (but not all) times when exposed to weak noise pulses from extremely distant (>300 km) seismic exploration (Bowles et al. 1994). This "quieting" was suspected to represent a disturbance effect, in part because sperm whales exposed to pulsed man-made sounds at higher frequencies often cease calling (Watkins and Schevill 1975; Watkins et al. 1985). Also, sperm whales in the Gulf of Mexico may have moved away from a seismic vessel (Mate et al. 1994).

On the other hand, recent (and more extensive) data from vessel-based monitoring programs in U.K. waters suggest that sperm whales in that area show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (Stone 2003). These types of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive species or individuals, which may be beyond visual range. However, the U.K. results do seem to show considerable tolerance of seismic surveys by at least some sperm whales. Also, a recent study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 µPa pk-pk (Madsen et al. 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale vocalizations at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). An experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico is presently underway (Caldwell 2002; Jochens and Biggs 2003), along with a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys (Mate 2003). During two controlled exposure experiments where sperm whales were exposed to seismic pulses at received levels 143–148 dB re 1 µPa, there was no indication of avoidance of the vessel or changes in feeding efficiency (Jochens and Biggs 2003). The received sounds were measured on an "rms over octave band with most energy" basis (P. Tyack, pers. comm.); the broadband rms value would be somewhat higher. Although the sample size from the initial work was small (four whales during two experiments), the results are consistent with those off northern Norway.

Conclusions.—Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies, especially near the U.K., show localized avoidance. Belugas summering in the Beaufort Sea tended to avoid waters out to 10–20 km from an operating seismic vessel. In contrast, recent studies show little evidence of reactions by sperm whales to airgun pulses, contrary to earlier indications.

There are no specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance. There is increasing evidence that some beaked whales may strand after exposure to strong noise from sonars. Whether they ever do so in response to seismic survey noise is unknown.

Pinnipeds

Few studies of the reactions of pinnipeds to noise from open-water seismic exploration have been published (for review, see Richardson et al. 1995). However, pinnipeds have been observed during a number of seismic monitoring studies. Monitoring in the Beaufort Sea during 1996–2002 provided a substantial amount of information on avoidance responses (or lack thereof) and associated behavior. Pinnipeds exposed to seismic surveys have also been observed during seismic surveys along the U.S. west coast. Some limited data are available on physiological responses of pinnipeds exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals exposed to noise from airguns and linear explosive charges reportedly did not react strongly (J. Parsons *in* Greene et al. 1985). An airgun caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear (Anonymous 1975). Pinnipeds in both water and air sometimes tolerate strong noise pulses from non-explosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Mate and Harvey 1987; Reeves et al. 1996). Thus, pinnipeds are expected to be rather tolerant of, or habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

In the U.K., a radio-telemetry study has demonstrated short-term changes in the behavior of harbor (=common) seals and grey seals exposed to airgun pulses (Thompson et al. 1998). In this study, harbor seals were exposed to seismic pulses from a 90 in^3 array (3 × 30 in^3 airguns), and behavioral responses differed among individuals. One harbor seal avoided the array at distances up to 2.5 km from the source and only resumed foraging dives after seismic stopped. Another harbor seal exposed to the same small airgun array showed no detectable behavioral response, even when the array was within 500 m. All grey seals exposed to a single 10 in^3 airgun showed an avoidance reaction. Seals moved away from the source, increased swim speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appeared to be short-term as all grey seals either remained in, or returned at least once to, the foraging area where they had been exposed to seismic pulses. These results suggest that there are interspecific as well as individual differences in seal responses to seismic sounds.

Off California, visual observations from a seismic vessel showed that California sea lions "typically ignored the vessel and array. When [they] displayed behavior modifications, they often appeared to be reacting visually to the sight of the towed array. At times, California sea lions were attracted to the array, even when it was on. At other times, these animals would appear to be actively avoiding the vessel and array" (Arnold 1996). In Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating; both species tended to orient away whether or not the airguns were firing (Calambokidis and Osmek 1998).

Monitoring work in the Alaskan Beaufort Sea during 1996–2001 provided considerable information regarding the behavior of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6–16 airguns with total volumes 560–1500 in^3. The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the airguns were operating then when they were not (Moulton and Lawson 2002). However, these avoidance movements were relatively small, on the order of 100 m to (at most) a few hundreds of meters, and many seals remained within 100–200 m of the trackline as the operating airgun array passed by. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997.

The operation of the airgun array had minor and variable effects on the behavior of seals visible at the surface within a few hundred meters of the array (Moulton and Lawson 2002). The behavioral data indicated that some seals were more likely to swim away from the source vessel during periods of airgun operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to airgun noise and proportions of seals engaged in other recognizable behav-iors, e.g., "looked" and "dove". Such a relationship might have occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced airgun noise levels close to the surface where "looking" occurs (Moulton and Lawson 2002).

Monitoring results from the Canadian Beaufort Sea during 2001-02 were more variable (Miller et al. 2005). During 2001, sighting rates of seals (mostly ringed seals) were similar during all seismic states, including periods without airgun operations. However, seals were seen closer to the vessel during non-seismic than seismic periods. In contrast, during 2002, sighting rates of seals were higher during non-seismic periods than seismic operations, and seals were seen farther from the vessel during non-seismic compared to seismic activity (a marginally significant result). The combined data for both years showed that sighting rates were higher during non-seismic periods compared to seismic periods, and that sighting distances were similar during both seismic states. Miller et al. (2005) concluded that seals showed very limited avoidance to the operating airgun array.

In summary, visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior. These studies show that pinnipeds frequently do not avoid the area within a few hundred meters of an operating airgun array. However, initial telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies.

Fissipeds.—Behavior of sea otters along the California coast was monitored by Riedman (1983, 1984) while they were exposed to a single 100 in^3 airgun and a 4089 in^3 array. No disturbance reactions were evident when the airgun array was as close as 0.9 km. Otters also did not respond noticeably to the single airgun. The results suggest that sea otters may be less responsive to marine seismic pulses than other marine mammals. Also, sea otters spend a great deal of time at the surface feeding and grooming. While at the surface, the potential noise exposure of sea otters would be much reduced by the pressure release effect at the surface.

(f) Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, but there has been no specific documentation of this in the case of exposure to sounds from seismic surveys. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds exceeding 180 and 190 dB re 1 μPa (rms), respectively (NMFS 2000). Those criteria have been used in establishing the safety (=shut-down) radii planned for numerous seismic surveys. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed below,

- the 180 dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid temporary auditory impairment let alone permanent auditory injury, at least for delphinids.
- temporary threshold shift (TTS) is not injury and does not constitute "Level A harassment" in MMPA terminology.
- the minimum sound level necessary to cause permanent hearing impairment ("Level A harassment") is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage.

Several aspects of the monitoring and mitigation measures that are now often implemented during seismic survey projects are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might cause hearing impairment. In addition, many cetaceans show some avoidance of the area with ongoing seismic operations (see above). In these cases, the avoidance responses of the animals themselves will reduce or avoid the possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds.

Temporary Threshold Shift (TTS)

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. TTS can last from minutes or hours to (in cases of strong TTS) days. However, it is a temporary phenomenon, and (especially when mild) is not considered to represent physical damage or "injury". Rather, the onset of TTS is an indicator that, if the animals is exposed to higher levels of that sound, physical damage is ultimately a possibility.

The magnitude of TTS depends on the level and duration of noise exposure, among other considerations (Richardson et al. 1995). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. Only a few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound.

Toothed Whales.—Ridgway et al. (1997) and Schlundt et al. (2000) exposed bottlenose dolphins and beluga whales to single 1-s pulses of underwater sound. TTS generally became evident at received levels of 192 to 201 dB re 1 μPa rms at 3, 10, 20, and 75 kHz, with no strong relationship between frequency and onset of TTS across this range of frequencies. At 75 kHz, one dolphin exhibited TTS at 182 dB, and at 0.4 kHz, no dolphin or beluga exhibited TTS after exposure to levels up to 193 dB (Schlundt et al. 2000). There was no evidence of permanent hearing loss; all hearing thresholds returned to baseline values at the end of the study.

Finneran et al. (2000) exposed bottlenose dolphins and a beluga whale to single underwater pulses designed to generate sounds with pressure waveforms similar to those produced by distant underwater explosions. Pulses were of 5.1 to 13 ms in duration, and the measured frequency spectra showed a lack of energy below 1 kHz. Exposure to those impulses at peak received SPLs (sound pressure levels) of up to 221 dB re 1 μPa did not produce temporary threshold shift, although disruption of the animals' trained behaviors occurred.

A similar study was conducted by Finneran et al. (2002) using an 80 in^3 water gun, which generated impulses with higher peak pressures and total energy fluxes than used in the aforementioned study. Water gun impulses were expected to contain proportionally more energy at higher frequencies than airgun pulses (Hutchinson and Detrick 1984). "Masked TTS" (MTTS refers to the fact that measurements were obtained under conditions with substantial, but controlled, background noise) was observed in a beluga after exposure to a single impulse with peak-to-peak pressure of 226 dB re 1 μPa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1 $\mu Pa^2 \cdot s$. Thresholds returned to within 2 dB of pre-exposure value ~4 min after exposure. No MTTS was observed in a bottlenose dolphin exposed to one pulse with peak-to-peak pressure of 228 dB re 1 μPa, equivalent to peak pressure 207 kPa and total energy flux of 188 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2002). In this study, TTS was defined as occurring when there was a 6 dB or larger increase in post-exposure thresholds. Pulse duration at the highest exposure levels, where MTTS became evident in the beluga, was typically 10–13 ms.

The data quoted above all concern exposure of small odontocetes to single pulses of duration 1 s or shorter, generally at frequencies higher than the predominant frequencies in airgun pulses. With single short pulses, the TTS threshold appears to be (to a first approximation) a function of the energy content of the pulse (Finneran et al. 2002). The degree to which this generalization holds for other types of signals is unclear (Nachtigall et al. 2003).

Finneran et al. (2005) examined the effects of tone duration on TTS in bottlenose dolphins. Bottlenose dolphins were exposed to 3 kHz tones for periods of 1, 2, 4 or 8 s, with hearing tested at 4.5 kHz. For 1-s exposures, TTS occurred with SELs of 197 dB, and for exposures >1 s, SEL $\geq$195 dB resulted in TTS. (SEL is equivalent to energy flux, in dB re 1 $\mu Pa^2 \cdot s$.) At SEL of 195 dB, the mean TTS (4 min after exposure) was 2.8 dB. Finneran et al. (2005) suggested that an SEL of 195 dB is the likely threshold for the onset of TTS in dolphins and white whales exposed to mid-frequency tones of durations 1-8 s, i.e., TTS onset occurs at a near-constant SEL, independent of exposure duration. That implies that a doubling of exposure time results in a 3 dB lower TTS threshold.

Mooney et al. (2005) exposed a bottlenose dolphin to octave-band noise ranging from 4 to 8 kHz at SPLs of 160 to 172 dB re 1 μPa for periods of 1.8 to 30 min. Recovery time depended on the shift and frequency, but full recovery always occurred within 40 min (Mooney et al. 2005). They reported that to induce TTS in a bottlenose dolphin, there is an inverse relationship of exposure time and SPL; as a first approximation, as exposure time was halved, an increase in noise SPL of 3 dB was required to induce the same amount of TTS.

Additional data are needed in order to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. Given the results of the aforementioned studies and a seismic pulse duration (as received at close range) of ~20 ms, the received level of a single seismic pulse might need to be on the order of 210 dB re 1 μPa rms (~221–226 dB pk-pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 100 m around a seismic vessel.

To better characterize this radius, it would be necessary to determine the total energy that a mammal would receive as an airgun array approached, passed at various CPA distances, and moved away. At the present state of knowledge, it would also be necessary to assume that the effect is directly related to total energy even though that energy is received in multiple pulses separated by gaps. The lack of data on the exposure levels necessary to cause TTS in toothed whales when the signal is a series of pulsed sounds, separated by silent periods, is a data gap

Baleen Whales.—There are no data, direct or indirect, on levels or properties of sound that are required to induce TTS in any baleen whale. However, in practice during seismic surveys, no cases of TTS are expected given the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for there to be any possibility of TTS. (See above for evidence concerning avoidance responses by baleen whales.) This assumes that the ramp up (soft start) procedure is used when commencing airgun operations, to give whales near the vessel the opportunity to move away before they are exposed to sound levels that might be strong enough to elicit TTS. As discussed above, single-airgun experiments with bowhead, gray, and humpback whales show that those species do tend to move away when a single airgun starts firing nearby, which simulates the onset of a ramp up.

Pinnipeds.—TTS thresholds for pinnipeds exposed to brief pulses (either single or multiple) of underwater sound have not been measured. Two California sea lions did not incur TTS when exposed to single brief pulses with received levels (rms) of ~178 and 183 dB re 1 µPa and total energy fluxes of 161 and 163 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2003). However, initial evidence from prolonged exposures suggested that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations. For sounds of relatively long duration (20–22 min), Kastak et al. (1999) reported that they could induce mild TTS in California sea lions, harbor seals, and northern elephant seals by exposing them to underwater octave-band noise at frequencies in the 100–2000 Hz range. Mild TTS became evident when the received levels were 60–75 dB above the respective hearing thresholds, i.e., at received levels of about 135–150 dB. Three of the five subjects showed shifts of ~4.6–4.9 dB and all recovered to baseline hearing sensitivity within 24 hours of exposure.

Schusterman et al. (2000) showed that TTS thresholds of these pinnipeds were somewhat lower when the animals were exposed to the sound for 40 min than for 20–22 min, confirming that there is a duration effect in pinnipeds. Similarly, Kastak et al. (2005) reported that threshold shift magnitude increased with increasing SEL in a California sea lion and harbor seal. They noted that doubling the exposure duration from 25 to 50 min i.e., +3 dB change in SEL had a greater effect on TTS than an increase of 15 dB (95 vs. 80 dB) in exposure level. Mean threshold shifts ranged from 2.9–12.2 dB, with full recovery within 24 h (Kastak et al. 2005). Kastak et al. (2005) suggested that sound exposure levels resulting in TTS onset in pinnipeds may range from 183 to 206 dB re 1 $\mu Pa^2 \cdot s$, depending on the absolute hearing sensitivity.

There are some indications that, for corresponding durations of sound, the harbor seal may incur TTS at somewhat lower received levels than do small odontocetes (Kastak et al. 1999, 2005; Ketten et al. 2001; *cf*. Au et al. 2000). However, TTS onset in the California sea lion and northern elephant seal may occur at a similar sound exposure level as in odontocetes (Kastak et al. 2005).

Likelihood of Incurring TTS.—A marine mammal within a radius of ≤100 m around a typical array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel.

As shown above, most cetaceans show some degree of avoidance of seismic vessels operating an airgun array. It is unlikely that these cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. TTS would be more likely in any odontocetes that bow- or wake-ride or otherwise linger near the airguns. However, while bow- or wake-riding, odontocetes would be at or above the surface and thus not exposed to strong sound pulses given the pressure-release effect at the surface. But if bow-or wake-riding animals were to dive intermittently near airguns, they would be exposed to strong sound pulses, possibly repeatedly. If some cetaceans did incur mild or moderate TTS through exposure to airgun sounds in this manner, this would very likely be a temporary and reversible phenomenon.

Some pinnipeds show avoidance reactions to airguns, but their avoidance reactions are not as strong or consistent as those of cetaceans (see above). Pinnipeds occasionally seem to be attracted to operating seismic vessels. As previously noted, there are no specific data on TTS thresholds of pinnipeds exposed to single or multiple low-frequency pulses. It is not known whether pinnipeds near operating seismic vessels, and especially those individuals that linger nearby, would incur significant TTS.

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1 μPa (rms). The corresponding limit for pinnipeds has been set at 190 dB, although the HESS Team (1999) recommended a 180-dB limit for pinnipeds in California. The 180 and 190 dB (rms) levels are not considered to be the levels above which TTS might occur. Rather, they are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before any TTS measurements for marine mammals were available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As discussed above, TTS data that have subsequently become available imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to airgun pulses stronger than 180 dB re 1 μPa rms. Furthermore, it should be noted that mild TTS is not injury, and in fact is a natural phenomenon experienced by marine and terrestrial mammals (including humans).

It has been shown that most large whales tend to avoid ships and associated seismic operations. In addition, ramping up airgun arrays, which is standard operational protocol for many seismic operators, should allow cetaceans to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array. [Three species of baleen whales that have been exposed to pulses from single airguns showed avoidance (Malme et al. 1984–1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b). This strongly suggests that baleen whales will begin to move away during the initial stages of a ramp up, when a single airgun is fired.] Thus, whales will likely not be exposed to high levels of airgun sounds. Likewise, any whales close to the trackline could move away before the sounds from the approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment. Therefore, there is little potential for whales to be close enough to an airgun array to experience TTS. Furthermore, in the event that a few individual cetaceans did incur TTS through exposure to airgun sounds, this is a temporary and reversible phenomenon.

Permanent Threshold Shift (PTS)

When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, while in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges. Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times (time required for sound pulse to reach peak pressure from the baseline pressure). Such damage can result in a permanent decrease in functional sensitivity of the hearing system at some or all frequencies.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the likelihood that some mammals close to an airgun array might incur at least mild TTS (see Finneran et al. 2002), there has been speculation about the possibility that some individuals occurring very close to airguns might incur TTS (Richardson et al. 1995, p. 372*ff*).

Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Relationships between TTS and PTS thresholds have not been studied in marine mammals but are assumed to be similar to those in humans and other terrestrial mammals. The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during recent controlled studies of TTS have been confirmed to be temporary, with no measurable residual PTS (Kastak et al. 1999; Schlundt et al. 2000; Finneran et al. 2002; Nachtigall et al. 2003, 2004). However, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter 1985). In terrestrial mammals, the received sound level from a single non-impulsive sound exposure must be far above the TTS threshold for any risk of permanent hearing damage (Kryter 1994; Richardson et al. 1995). However, there is special concern about strong sounds whose pulses have very rapid rise times. In terrestrial mammals, there are situations when pulses with rapid rise times can result in PTS even though their levels are only a few dB higher than the level causing slight TTS. The rise time of airgun pulses is fast, but not nearly as fast as that of explosions, which are the main concern in this regard.

Some factors that contribute to onset of PTS, at least in terrestrial mammals, are as follows:

- exposure to single very intense sound,
- repetitive exposure to intense sounds that individually cause TTS but not PTS, and
- recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) has reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rather rapid rise time.

Sound impulse duration, peak amplitude, rise time, and number of pulses are the main factors thought to determine the onset and extent of PTS. Based on existing data, Ketten (1994) has noted that the criteria for differentiating the sound pressure levels that result in PTS (or TTS) are location and species-specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

Given that marine mammals are unlikely to be exposed to received levels of seismic pulses that could cause TTS, it is highly unlikely that they would sustain permanent hearing impairment. If we assume that the TTS threshold for exposure to a series of seismic pulses may be on the order of 220 dB re 1 μPa (pk-pk) in odontocetes, then the PTS threshold might be as high as 240 dB re 1 μPa (pk-pk) or 10 bar-m. Such levels are found only in the immediate vicinity of the largest airguns (Richardson et al. 1995:137; Caldwell and Dragoset 2000). It is very unlikely that an odontocete would remain within a few meters of a large airgun for sufficiently long to incur PTS. The TTS (and thus PTS) thresholds of baleen whales and/or pinnipeds (e.g., harbor seal) may be lower, and thus may extend to a somewhat greater distance. However, baleen whales generally avoid the immediate area around operating seismic vessels, so it is unlikely that a baleen whale could incur PTS from exposure to airgun pulses. Pinnipeds, on the other hand, often do not show strong avoidance of operating airguns.

Although it is unlikely that airgun operations during most seismic surveys would cause PTS in marine mammals, caution is warranted given the limited knowledge about noise-induced hearing damage in marine mammals, particularly baleen whales. Commonly-applied monitoring and mitigation measures, including visual monitoring, course alteration, ramp ups, and power downs or shut downs of the airguns when mammals are seen within the "safety radii", would minimize the already-low probability of exposure of marine mammals to sounds strong enough to induce PTS.

(g) Strandings and Mortality

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding. However, the spatiotemporal association of mass strandings of beaked whales with naval exercises and an L-DEO seismic survey in 2002 has raised the possibility that beaked whales may be especially susceptible to injury and/or behavioral reactions that can lead to stranding when exposed to strong pulsed sounds.

In March 2000, several beaked whales that had been exposed to repeated pulses from high intensity, mid-frequency military sonars stranded and died in the Providence Channels of the Bahamas Islands, and were subsequently found to have incurred cranial and ear damage (NOAA and USN 2001). Based on post-mortem analyses, it was concluded that an acoustic event caused hemorrhages in and near the auditory region of some beaked whales. These hemorrhages occurred before death. They would not necessarily have caused death or permanent hearing damage, but could have compromised hearing and navigational ability (NOAA and USN 2001). The researchers concluded that acoustic exposure caused this damage and triggered stranding, which resulted in overheating, cardiovascular collapse, and physiological shock that ultimately led to the death of the stranded beaked whales. During the event, five naval vessels used their AN/SQS-53C or -56 hull-mounted active sonars for a period of 16 h. The sonars produced narrow (<100 Hz) bandwidth signals at center frequencies of 2.6 and 3.3 kHz (-53C), and 6.8 to 8.2 kHz (-56). The respective source levels were usually 235 and 223 dB re 1 μPa, but the -53C briefly operated at an unstated but substantially higher source level. The unusual bathymetry and constricted channel where the strandings occurred were conducive to channeling sound. This, and the extended operations by multiple sonars, apparently prevented escape of the animals to the open sea. In addition to the strandings, there are reports that beaked whales were no longer present in the Providence Channel region after the event, suggesting that other beaked whales either abandoned the area or perhaps died at sea (Balcomb and Claridge 2001).

Other strandings of beaked whales associated with operation of military sonars have also been reported (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998). In these cases, it was not determined whether there were noise-induced injuries to the ears or other organs. Another stranding of beaked whales (15 whales) happened on 24–25 September 2002 in the Canary Islands, where naval maneuvers were taking place. Based on the strandings in the Canary Islands, Jepson et al. (2003) proposed that cetaceans might be subject to decompression injury in some situations. Fernández et al. (2005a) showed that those beaked whales did indeed have gas bubble-associated lesions and fat embolisms. Fernández et al. (2005b) also found evidence of fat embolism in three beaked whales that stranded 100 km north of the Canaries in 2004 during naval exercises. Examinations of several other stranded species have also revealed evidence of gas and fat embolisms (e.g., Arbelo et al. 2005; Jepson et al. 2005a; Méndez et al. 2005). These effects were suspected to be induced by exposure to sonar sounds, but the mechanism of injury was not auditory. Most of the afflicted species were deep divers. Gas and fat embolisms may occur if cetaceans ascend unusually quickly when exposed to aversive sounds, or if sound in the environment causes the destabilization of existing bubble nuclei (Potter 2004; Moore and Early 2004; Arbelo et al. 2005; Fernández et al. 2005a; Jepson et al. 2005b). Previously it was widely assumed that diving marine mammals are not subject to the bends or air embolism.

It is important to note that seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by the types of airgun arrays used to profile sub-sea geological structures are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time (though the center frequency may change over time). Because seismic and sonar sounds have considerably different characteristics and duty cycles, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar pulses can, in special circumstances, lead directly or indirectly to mortality suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

As noted earlier, in Sept. 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California (Mexico) when a seismic survey by the R/V *Maurice Ewing* was underway in the general area. (Malakoff 2002). The airgun array in use during that project was the *Ewing*'s 20-airgun 8490-in^3 array. This might be a first indication that seismic surveys can have effects, at least on beaked whales, similar to the suspected effects of naval sonars. However, the evidence linking the Gulf of California strandings to the seismic surveys was inconclusive, and not based on any physical evidence (Hogarth 2002; Yoder 2002). The ship was also operating its multibeam bathymetric sonar at the same time but, as discussed elsewhere, this sonar had much less potential than the aforementioned naval sonars to affect beaked whales. Although the link between the Gulf of California strandings and the seismic (plus multi-beam sonar) survey is inconclusive, this plus the various incidents involving beaked whale strandings "associated with" naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales.

(h) Non-auditory Physiological Effects

Possible types of non-auditory physiological effects or injuries that might theoretically occur in marine mammals exposed to strong underwater sound might include stress, neurological effects, bubble formation, and other types of organ or tissue damage. However, studies examining such effects are limited. If any such effects do occur, they would probably be limited to unusual situations. Those could include cases when animals are exposed at close range for unusually long periods, or when the sound is strongly channeled with less-than-normal propagation loss, or when dispersal of the animals is constrained by shorelines, shallows, etc.

Long-term exposure to anthropogenic noise may have the potential of causing physiological stress that could affect the health of individual animals or their reproductive potential, which in turn could (theoretically) cause effects at the population level (Gisiner [ed.] 1999). Romano et al. (2004) examined the effects of single underwater impulse sounds from a seismic water gun (up to 228 dB re 1 μPa peak-to peak pressure) and single pure tones (sound pressure level up to 201 dB re 1 μPa) on the nervous and immune systems of a beluga and a bottlenose dolphin. They found that neural-immune changes to noise exposure were minimal. Although levels of some stress-released substances (e.g., catecholamines) changed significantly with exposure to sound, levels returned to baseline after 24 hr. Further information about the occurrence of noise-induced stress in marine mammals is not available at this time. However, it is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop. This is particularly so in the case of seismic surveys where the tracklines are long and/or not closely spaced.

High sound levels could potentially cause bubble formation of diving mammals that in turn could cause an air or fat embolism, tissue separation, and high, localized pressure in nervous tissue (Gisiner [ed.] 1999; Houser et al. 2001). Moore and Early (2004) suggested that sperm whales are subjected to natural bone damage caused by repeated decompression events during their lifetimes. Those authors hypothesized that sperm whales are neither anatomically nor physiologically immune to the effects of deep diving. The possibility that marine mammals may be subject to decompression sickness was first explored at a workshop (Gentry [ed.] 2002) held to discuss whether the stranding of beaked whales in the Bahamas in 2000 (Balcomb and Claridge 2001; NOAA and USN 2001) might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused this stranding. Among other reasons, the air spaces in marine mammals are too large to be susceptible to resonant frequencies emitted by mid- or low-frequency sonar; lung tissue damage has not been observed in any mass, multi-species stranding of beaked whales; and the duration of sonar pings is likely too short to induce vibrations that could damage tissues (Gentry [ed.] 2002). Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales. Workshop participants did not rule out the possibility that bubble formation/growth played a role in the stranding and participants acknowledged that more research is needed in this area.

Jepson et al. (2003) first suggested a possible link between mid-frequency sonar activity and acute and chronic tissue damage that results from the formation *in vivo* of gas bubbles, based on 14 beaked whales that stranded in the Canary Islands close to the site of an international naval exercise in September 2002. The interpretation that the effect was related to decompression injury was initially unproven (Piantadosi and Thalmann 2004; Fernández et al. 2004). However, there is increasing evidence and suspicion that decompression illness can occur in beaked whales and perhaps some other odontocetes, and that there may, at times, be a connection to noise exposure (see preceeding section).

Gas and fat embolisms may occur if cetaceans ascend unusually quickly when exposed to aversive sounds, or if sound in the environment causes the destabilization of existing bubble nuclei (Potter 2004; Moore and Early 2004; Arbelo et al. 2005; Fernández et al. 2005a; Jepson et al. 2005b). Thus, air and fat embolisms could be a mechanism by which exposure to strong sounds could, indirectly, result in non-auditory injuries and perhaps death. However, even if those effects can occur during exposure to mid-frequency sonar, there is no evidence that those types of effects could occur in response to airgun sounds.

The only available information on acoustically-mediated bubble growth in marine mammals is modeling assuming prolonged exposure to sound. Crum et al. (2005) tested *ex vivo* bovine liver, kidney, and blood to determine the potential role of short pulses of sound to induce bubble nucleation or decompression sickness. In their experiments, supersaturated bovine tissues and blood showed extensive bubble production when exposed to low-frequency sound. Exposure to 37 kHz at ~50 kPa caused bubble formation in blood and liver tissue, and exposure to three acoustic pulses of 10,000 cycles, each 1 min, also produced bubbles in kidney tissue. Crum et al. (2005) speculated that marine mammal tissue may be affected in similar ways under such conditions. However, these results may not be directly applicable to free-ranging marine mammals exposed to sonar.

In summary, very little is known about the potential for seismic survey sounds to cause either auditory impairment or other non-auditory physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects.

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